SCIENTIFIC AMERICAN SUPPLEMENT

VOLUME LXXVII NUMBER 1998] NEW YORK, APRIL 18, 1914 [10 CENTS A COPY $5.00 A YEAR

A Comparison of Rivers

The Amazon's Discharge Exceeds the Aggregate of all North American Rivers

By J. Whitman Bailey

Although comparative geography possesses unusual interest, most publications relating thereto treat solely of natural products and populations. We are unable to find, for instance, a single book or pamphlet that takes a comprehensive view of all the world's important rivers, compares their salient characteristics and arranges them in typical groups. The few works that bear such titles as "Rivers" or "Rivers of the World," mention merely a limited number of the best-known streams, while the descriptions are rarely comparative and usually largely historical. Comparisons usually begin and end with such tables of lengths, areas and estimates of discharge—the latter varying widely—as are found in geographies. Our encyclopædias, under the general heading, "Rivers," contain curiously brief articles, while the separate river descriptions are not to any extent comparative, and much too widely scattered to admit of any general view.

We all know of the Amazon as the world's greatest river, but how many of us realize that, if all North American rivers, great and small, could be turned into a common channel, the resulting stream would fall short in volume of that colossal water mass, estimated at from four to five million cubic feet per second, which constitutes the Amazon's mean annual discharge into the Atlantic? Without doubt the Congo is the world's second river. But what river holds third place? Although we would like to see our Mississippi thus laurel-crowned, the weight of evidence, so far as relates to mean volume, favors either the Yang-tse-Kiang, Parana or Orinoco; or the Madeira, chief tributary of the Amazon. Different hydrographers, including Sir John Murray, have made tables, always omitting from them various quite important rivers, but as these gentlemen differ quite widely in their conclusions, the questions involved, except in the case of a few carefully studied streams, must still be considered somewhat open. The leanest rivers of any great length, observed at low water, are the Murray of Australia, Senegal and Orange of Africa and our own Rio Grande.

What, by the way, is a river? The word has been even more variously applied than the word "mountain." Mere brooks of one country would be rivers in another. The "Encyclopædia Britannica" defines a river as "any considerable stream of water flowing in a defined channel." This is rather vague, as the word "considerable" has no fixed value, besides, it leaves us in doubt as to whether the longest headstream or the one of greatest volume should be followed. Streams, too, may be salt or fresh. The Straits of Gibraltar and the Dardanelles contain considerable streams that flow one way, at least on the surface, in clearly defined channels. Geographers are beginning to think favorably of the idea that a river is a moving body of fresh water, with or without occasional lake expansions, that originates with its most voluminous head stream, and is continued downward to a point where its waters merge in some greater river system, or, as the case may be, to a point, often quite difficult to determine exactly, where the salt water, at low tide, predominates over the fresh. Some agreement

(*Continued on page 244*).

The Fraser River.

A COMPARISON OF RIVERS.

Bearing Metal Manufacturing and Use*

The Characteristics of Metals Used for Bearings

By L. D. Allen

"It is not work that kills men, it is worry." It is not motion that destroys machinery, it is friction.

Friction, a destructive agent, constantly piling up waste and expense, is everywhere. And yet, of the many details connected with the operation and care of machinery, it is doubtful if any receive less attention than the reduction of friction. In many installations, the shafting alone requires from 20 to 30 per cent of the power developed by the engine, and in some cases these figures are probably greatly exceeded. Comparatively few realize the significance of these figures, which mean that of every ton of fuel consumed some 400 pounds or more are wasted in overcoming friction. Much of such waste can be greatly reduced, but in the rush of getting out work, such as prevails in many mills and factories, few, if any, have the time and patience to go into details and correct bad conditions. The prevailing idea seems to be that greatest economy will be effected by buying at a low price rather than by securing efficiency and reduction in wear through the use of suitable material and methods.

Power lost through friction is converted into heat, which under normal conditions is radiated as fast as produced, the bearing surfaces remaining at or near the temperature of the surrounding air. If the heat is generated faster than it is dissipated, a hot or fused bearing will result. For this reason, the anti-frictional properties of a bearing metal are more desirable than tensile and compression strength. Many judge a metal by its compression strength and its tin content, whereas, under high speed, metals high in tin are usually the first to heat and fuse. It makes no difference how much tin a metal contains, how hard it is or how great its compression strength, if it heats it will soon fuse and run out of the bearing, and under such conditions it is no better than so much lead.

CAUSE AND COST OF FRICTION.

Resistance to motion—friction—is great or small according to the roughness or unevenness of the surfaces in moving contact. In reality, there are no absolutely smooth metal surfaces. A surface may seem smooth to the touch, but by means of a powerful lens, minute projections, roughness and unevenness may be seen, which create the resistance. By proper lubrication, a film of lubricant is established and maintained between the rubbing surfaces which tends to prevent the irregularities from meshing. The conditions for this film are favorable only to such extent as the bearing and shaft are smooth.

To a greater extent than most people realize, the "cost of the babbitt or the lubricant is the cost of the friction accompanying the same."

A concern may spend several dollars less, per hundred pounds, for a babbitt that will show apparently satisfactory wear, but the question is how much money does this concern spend on other things as a result of the friction developed from the use of this particular babbitt. It may not even heat in a slow-running bearing, but if it is low in anti-frictional qualities, it communicates to the other parts of the machinery a certain amount of pull and drag, and this percentage, even though small in any one bearing, develops to considerable proportions in the aggregate friction of all the bearings throughout a plant.

BABBITT REQUIREMENTS.

The requirements of a babbitt are: First, that it be composed of metals least susceptible to frictional contact; second, that it possess the sustaining properties necessary to carry the load imposed; third, that the ingredients be so treated, reduced and combined as to produce an even, smooth, unctuous surface, which will minimize interlocking, abrasion and friction in its various forms.

The metals used in the manufacture of the various babbitts, type metals, solders, etc., are two or more of the following: Tin, lead, copper, antimony and bismuth. Some idea of the bearing value of these different metals may be derived from the properties of each as enumerated herewith.

PROPERTIES OF TIN.

Tin is a white metal with a yellowish tinge. It toughens the alloy, lowers the melting point and assists in producing a strong, homogeneous mixture. It is a "dry" metal, that is, somewhat lacking in anti-frictional properties. Under heavy friction, it heats quickly and fuses. Over direct heat, it melts at about 450 deg. Fahr.; its specific gravity is 7.35. The grade generally used in the manufacture of babbitt metals is known as Straits tin. There are now in this country a number of detinning concerns which are producing a nearly pure tin by either a chemical or sweating process from old scrap, tin cans, etc. This is now being used extensively in the manufacture of babbitts and cheap solders, as it can be bought at about a cent per pound under the market price.

LEAD.

Lead is another ore product and imparts softness, lowers the melting point and reduces the tendency to heat. It reduces friction more than any other metal, resembling graphite in this respect. It melts over direct heat at about 620 deg. Fahr., and its specific gravity is 11.38. In many sections, considerable antimony ore is found combined with the lead ore, so that in the process of refining the lead, a slag or by-product results, which is known as antimonial lead. This is put through a further refining process, which does not separate the lead from the antimony, but removes considerable of the impurities such as iron, arsenic, etc. The resultant product usually contains anywhere from 12 to 22 per cent antimony, the rest being lead and some impurities. This antimonial lead is used in making cheap babbitts, type metals, casting metals, etc., for competition where a low price is necessary.

COPPER.

Copper hardens and toughens the alloy and raises the melting point. It slightly increases friction. It melts at a temperature of 1,943 deg. Fahr., and its specific gravity is 8.85. Copper is the basis metal in bronze, brasses, etc. Very little of it is used in babbitt metal, from 0.25 to 0.5 per cent in a lead-based babbitt, although there are some mixtures that contain as much as 10 per cent copper, the hard babbitt, for instance, known as "Hard Genuine," containing 80 pounds of tin, 10 pounds of antimony and 10 pounds of copper. Copper and lead are not particularly fond of each other. The writer does not care for copper in a lead-based babbitt; it hardens the babbitt somewhat, but it reduces the anti-frictional value.

ANTIMONY.

Antimony is an imported ore product. It is a hard, brittle, bluish-white metal of crystalline structure. It hardens an alloy and raises the melting point. It is a great reducer of heat, and it also reduces friction. It melts over direct heat at about 1,169 deg. Fahr., and its specific gravity is 6.76. The crystalline grain or fracture in a babbitt is due to its antimony content. Some very carefully and scientifically conducted tests indicate that the best babbitts should not contain over 13 per cent antimony, as the evenness of the alloy and its wearing qualities are greatest at that point.

BISMUTH.

Bismuth reduces friction and prevents shrinkage. It lowers the melting point and expands on cooling. It melts at a temperature of about 507 deg. Fahr., and its specific gravity is 9.82. As bismuth usually costs more than $2 per pound, it is not at all popular with the babbitt manufacturer.

ALUMINIUM.

Aluminium is rarely used in a babbitt. It imparts some toughness by closing the grain and acts as a flux. It slightly increases the friction which offsets its toughening properties and makes it of no practical value in a babbitt.

Certain combinations of tin, copper and antimony shrink on cooling. Tin and lead alone shrink slightly, and antimony remains about constant. Any two metals mixed together in the form of an alloy produce a metal which melts at a lower temperature than the original metal having the higher melting point, and in some cases, lower than the metal with the lower melting point.

CLASSIFICATION OF BEARING METALS.

Bearing metals or linings may be classified under two heads, babbitt metals, which are largely tin, lead, antimony and sometimes copper compositions, and brasses and bronzes, which are tin, copper and zinc compositions, sometimes containing certain percentages of lead.

Babbitts range in composition from a cheap metal containing 90 pounds lead and 10 pounds antimony, to mixtures containing about 88 pounds tin, 4 pounds copper and 8 pounds antimony.

Babbitt metals are divided into three classes, the lead-based anti-friction metals, which are metals in which the lead content is the heaviest, the smaller percentages being tin and antimony; the semi-tin-based metals in which the tin and lead contents are about equal, leaving room for from 10 to 20 per cent antimony, and the tin-based metals, which range from 75 pounds up to 90 pounds of tin in each 100 pounds.

I have knowledge of over 200 different babbitt mixtures that are in actual use, whereas only about 7 or 8 are really necessary. Babbitt metals should be made according to certain exact percentages, or so constructed as to be evenly balanced, so as to produce perfectly homogeneous mixtures or alloys, in order that a combination may possess its maximum strength and hardness.

BEARING-METAL MANUFACTURERS.

There are four kinds of bearing- and type-metal manufacturers.

The first is the smelterer who buys and refines drosses, scrap metals, etc., and converts the resultant product into different grades of babbitt metals, type metals, solders, etc. He sells to a large trade, which is influenced or attracted by a low price; its requirements are large in the matter of quantity, but not exacting in the matter of quality.

The second is the man who installs a kettle, buys tin, lead and antimony and mixes them in certain proportions according to some one or set of published formulas. Not only are these published or analytical formulas, as a rule, incorrect, but they have very little to do with the details of producing the right kind of finished product. The amount of business he does is in proportion to his luck and hustle.

The third is a combination of the two foregoing classes.

The fourth is the experienced alloyist who has studied the properties of all the different metals, so that he knows which will combine best and how best to combine them—the best temperatures and fluxes to employ, etc. He has also, to combine with the foregoing data, a practical knowledge of the uses to which the metals are put. This type of man gets the discriminating, careful trade, which makes a thorough study and test of its needs and demands results accordingly, or which, in buying, places quality first.

MANUFACTURING REQUIREMENTS.

Many years of practical experience with the formulas and manufacturing methods employed by different babbitt manufacturers both in the United States and abroad, coupled with deductions from results shown by expert analytical and mechanical tests and under actual working conditions in nearly all kinds of machinery, indicate conclusively the following facts:

The best amalgams are produced by the alloying method. This requires the use of several furnaces, pure materials, and consists in making up, at suitable temperatures, certain primary combinations of affinity metals; then taking such quantity of each combination as is necessary to produce the required grade and alloying the same under suitable temperature into the finished product. Metals may be well mixed, but the quality and permanency of the mixture are determined by just such solubility laws as control ordinary solutions. Certain perfect amalgams at high temperature become partly separated amalgams at low temperature; others there are that remain perfect amalgams at any temperature.

In the use of the lead-antimony and the lead-antimony-tin mixtures a complete reduction of the crystal formation is important to insure smooth, mirror-like, non-abrasive bearing surfaces. All the ingredients must be evenly balanced and distributed throughout the alloy. It is for this reason that a lengthy annealing period is desirable because it has been found to have a greater effect on the mechanical properties of a metal than the temperature factor.

The tin, copper, zinc, aluminium, nickel, etc., amalgams are the most difficult to produce. They require skill and care in the introduction of deoxidizing agents, such as magnesium, phosphorus, silicon, etc.

VIRGIN VS. OLD METAL.

Very often large babbitt users who have their own formulas specify that "virgin" metal be used. Metallurgists claim that it is not a question of whether virgin metal or old metal be used so long as the metal is "pure," free from dissolved or mechanically entangled oxides. It is the oxides and impurities that impair repeatedly overheated or remelted metals. Some good authorities claim that the dross of tin, lead and antimony products (when free from iron, aluminium, zinc and arsenic) and smelted in an adequate reducing furnace at above 2,500 deg. Fahr., will, with the proper additions made to the resultant metal, produce amalgams that are superior to the same amalgams made from all virgin metals, because the amalgams will be better alloyed than when virgin metal is used. My experience, however, leads me to doubt this and to believe that chemically pure, perfectly balanced amalgams made of virgin metal produce the surest and strongest babbitt metals made, and that they possess higher anti-frictional properties.

CHEMICAL ANALYSIS ALONE NO GUIDE.

A babbitt should not be selected on analysis, as there is much that enters into the making of the metal, and

*Reproduced from *Power*.

that has to do with its physical properties, that evades the chemists. Nor should one babbitt be selected for all bearing requirements. Metals, heavy in lead are best anti-frictionally when properly alloyed, but metals heavy in tin and copper are also desirable where toughness combined with hardness is required to meet unusually severe or irregular bearing conditions.

Considering the price of lead and antimony, there is no legitimate reason for paying 18 cents to 25 cents per pound for bluish-looking or leady-looking metal, the tin content of which is usually not over 15 per cent, and often below 10 per cent. On the other hand, considering the high price of tin, no one should expect to pay much, if any, below the market price of tin for the whitish-looking or tin-based metals, or to go much below a medium figure for the semi-tin-based metals which are also white in appearance.

Babbitt troubles are often due to a good many things other than the babbitt itself. Some of these things are a selection of the wrong grade of metal; the wrong application of the metal; irregular bearing conditions; bad lubrication; neglect, etc.

The safest course for the purchaser who wishes to secure the best bearing values is to place his babbitt orders with such manufacturers only as are thoroughly experienced in bearing requirements, who know just what metals or combinations of metals possess the best endurance and anti-frictional properties, who are also thoroughly skilled in alloying and combining metals, and, as well, honest and conscientious in their trade relations.

Prices and analyses are usually dangerous factors to rely upon in the selection of a babbitt. The size of the bearing, the thickness of the lining, and the speed and load conditions should influence the choice. A properly made, hardened and strengthened lead-based babbitt will, oft-times, due to its naturally better anti-frictional properties, give better service than an expensive tin-based metal.

The Radiation Problem*

By E. E. Fournier d'Albe, D.Sc.

The radiation discussion, which was one of the most notable features of the Birmingham meeting of the British Association, appears to have created a general impression that some radical revision of our ideas as to the nature of radiation must now be regarded as unavoidable. It may therefore be of interest to give a brief summary of the present state of the problem.

Its acute phase has been brought about by the remarkable successes achieved by some forms of what is known as the "theory of quanta." This theory, or rather hypothesis, assumes that not only matter, but energy itself, has an atomistic or discontinuous structure, particularly when it is flung out into space in the form of radiant energy or radiation.

Are we, then, drifting back to a corpuscular emission theory of light, destined to replace the now generally accepted wave theory? Such a return to older views would not be altogether without precedent. History has witnessed similar fluctuations of view as regards the shape and motion of the earth, and as regards the structure of electricity. And the triumphs of atomistic conceptions in other fields, achieved with the aid of radioactivity and of Brownian motions, make the propaganda for a further extension of the atomistic principle easy. R. A. Millikan[1] maintains that the number of atoms and molecules in a given mass of matter may now be counted with as much certainty and precision as we can attain in counting the inhabitants of a city. With the characteristics of these inhabitants we can deal by means of the science of statistics, and the adherents of the new atomistic theory of radiation would have us apply statistical methods to an immense range of physical investigations.

But the hypothesis of "quanta" or irreducible and indivisible elements of energy is not merely atomism gone mad. There are certain undeniable and undoubted facts which find their simplest explanation in the hypothesis of a discrete structure of radiant energy.

Chief of these is the observed mode of transfer of energy from kathode-rays to X-rays, and *vice versa*. Kathode rays are electrons projected with enormous velocities. The stoppage of an electron by the target in the Roentgen tube generates an X-ray pulse. All electrons are stopped within a time which is the shorter the greater their energy of motion. Hence the X-ray pulse generated is "thin" in proportion as its energy is great. The more rapid the kathode rays, the thinner, "harder," and more penetrating are the X-rays.

Now the beautiful recent work on the reflection and interference of X-rays, often referred to in *Nature*, has proved that these rays are covered by the wave-theory of light. The X-ray waves are some 10,000 times shorter than the shortest ultra-violet light waves known. They have, like ordinary light, a wave-length, or rather a range of wave-lengths, and the energy of every X-ray wave is *proportional to its frequency*, since the thinner and "harder" pulses have the smaller wave-lengths.

But this is not all. When X-rays impinge on a target, electrons are projected from it; they in turn constitute kathode rays. The velocity of these electrons is independent of the intensity of the X-ray beam. It only depends upon its "hardness," i. e., its frequency, or the reciprocal of its wave-length. To put it in the language of visible light, the velocity with which an electron is expelled from the target depends, not upon the "brightness" of the X-rays, but solely upon their "color," and is the greater the more that color tends toward the "blue" end of the spectrum.

Moreover, those electrons which are not expelled from the material exposed to the X-rays appear to be quite unaffected, and they form the vast majority of the electrons present, unless a particular "characteristic frequency" is used for the existing rays, whereupon the electrons come out in enormous numbers.

The handing on of a quantity of energy intact from X-ray to kathode-ray and back to X-ray was used to support an atomistic view of the X-rays themselves, until it was found that the same rules apply to the liberation of electrons by ultar-violet light. Here arose a dilemma: either ultra-violet light itself (and probably all radiation) is atomic, or there is some mechanism by which radiant energy can be absorbed until a definite quantity (proportional to the frequency) is accumulated, whereupon an electron is expelled. The remarkable thing is that this energy of the electron is actually derived from the light, so that the latter does not simply liberate internal energy by some sort of "trigger" action.

All this might not have ensured a hearing for an atomistic hypothesis of energy had not Prof. Max Planck (now rector of Berlin University) put forward a theory of radiation based upon quite other considerations, which also involved an atomic structure of energy, at least when radiated.[2] He was endeavoring to explain the experimental fact that the total heat of all wave-lengths radiated by a black body (not a blackened body, but the "ideal" black represented, say, by the mouth of a deep cave) is proportional to the fourth power of its absolute temperature, and found that no formula completely representing the relation between the frequency and the amount of energy associated with it could be written down unless the energy was flung out by each molecular radiator in definite amounts or "quanta" proportional to the frequency, i. e., inversely proportional to the "wave-length." This immediately accounted for the fact that, as a body gets hotter, it passes from "red" heat to "white" heat (i. e., toward higher frequencies) until, when we reach the temperature of the sun, the maximum energy is well within the visible spectrum.

The actual magnitude of the supposed quanta is excessively small. For a frequency of one vibration per second, it would only amount to 6×10^{-27} erg, a quantity known as the "action constant." For frequencies like that of green light (600 billion per second) it would still only amount to some billionths of an erg, but such is the marvelous sensitiveness of the eye, that it can detect light (say, from a star of the sixth magnitude) when the amount of energy passing through the pupil is only some 300 or 400 quanta per second.

What, then, is the mechanism of this radiation by quanta? Are we to suppose that it resembles the sound waves proceeding from the incessant but irregular rifle fire of a large army, in which each soldier gradually accumulates sufficient powder to fire his shot? Or is it atomistic, like the bullets? Or must we fall back upon Sir J. J. Thomson's bold but rather appalling conception of a gigantic web of countless threads pervading the universe, in which each thread connects a positive and a negative electric atom, and bears its trembling message along with the speed of light in a single direction?

Whichever view may be finally adopted, we may be sure that the investigation of this fascinating problem will teach us a great deal about the interstellar ether which conveys the messages. The recent German attempt to explain away the ether, known as the electro-magnetic "Principle of Relativity," has failed in its main object. Gehrcke, in his preface to Drude's "Lehrbuch der Optik," describes that principle and its temporary sway as "the most notable case of mob suggestion since the days of the N-rays." The hypothesis of quanta is saved from a similar failure by keeping in close touch with experiment. In the hands of Nernst and Lindemann and Debye, it has been used with brilliant success for investigating and explaining the fall in the specific heat of all bodies as we approach the absolute zero of temperature. The specific heat probably begins by being proportional to the cube of the absolute temperature, so that the heat energy of the body is proportional to the fourth power, thus recalling the Stefan-Boltzmann law of total radiation already mentioned.

Planck's "action constant" has turned out a most useful quantity in all sorts of investigations, and, although its actual nature is somewhat doubtful,[3] it may yet turn out to be, like the velocity of light, one of the fundamental constants of nature.

But before any quantum theory of radiant energy can be accepted, it must make its peace with those phenomena (chiefly diffraction and interference) which overthrew Newton's emission theory, and established the wave theory of light. That has not yet been done, or even attempted, so there is but little prospect as yet of a decisive battle.

*Reproduced from *Nature*.

[1] *Science*, vol. xxxvii, p. 119, January 24th, 1913.

[2] "Vorlesungen über Wärmestrahlung," 2nd edition. (Leipzig, Barth.)

[3] It is an energy divided by a frequency, but also has been regarded as an angular momentum.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Mnemonic Rule for the Constant π

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

I was much interested in the French mnemonic for π which appeared in your issue of the 17th January. On consideration, however, it appeared to me that the device presented two defects—it was rather a lot to write out the words and then count the letters, and there seemed a probability that some words might be transposed, and even that two lines might be subject to the same error. I therefore set myself to devise a more mechanical mnemonic, and I venture now to submit the result.

There being no O in the series I take the first nine consonants to represent the units digits. These naturally falling into three groups separated by vowels considerably facilitates memorizing. Thus:

1	2	3	4	5	6	7	8	9
B	C	D	F	G	H	J	K	L

As the mnemonic may be useful for other sets of figures I should allocate letter M as the cipher.

These letters from B to L alone then have numerical significance—all consonants after M and all vowels may be ignored.

I now allocate these letters to the value of π, which I also divide into ten groups, getting nine groups of three and one of four figures. Thus:

3.14	159	265	358	979
DBF	BGL	CHG	DGK	LJL
323	846	264	338	3279
DCD	KFH	CHF	DDK	DCJL

Now all that is required is to select words for these ten groups of letters; and, so that transposition of the various groups shall not be possible, their order is determined by making the initial letter of a word to serve as an index of the position of the word; that is, the first group begins with B, the second group with C and so on, each "word" having four significant letters in proper order, first the index letter and then the letters of its group. For example, 3.14 may be represented by "braiseD BeeF"—the initial tells that the "word" is the first of the set; D (= 3) is the next significant letter and B (= 1) and F (= 4) are the only other significant letters. Obviously, other words might be selected giving the same result, "bad" and "brief" being examples.

On these lines I have selected the following series:

braiseD BeeF	=	3.14
caB GLass	=	159
disCHarGe	=	265
fonD GreeK	=	358
giLt JeweL	=	979
harD CoreD	=	323
junK FisH	=	846
kerCHieF	=	264
lanD DraKe	=	338
maD CaJoLer	=	3279

It will be seen that groups of three figures can be rigidly located, so that dislocation is scarcely possible; and as regards the various groups, it is well recognized that knowledge of the first letter of a wanted word is one of the most valuable of mnemonics. Doubtless a little more research would lead to a better selection of words, but even such a bizarre word as "junkfish" with its few non-significant letters has some advantages as a mnemonic.

A. J. STUBBS,
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On the Bow River. A source stream of the Nelson.

The Rhine Falls at Schaffhausen.

A Comparison of Rivers

(*Continued from first page*)

relating to size must also be arrived at. Perhaps a basin of 100 square miles, or a mean discharge of 200 second-feet, would be a convenient line of separation between rivers and brooks. The above definition would need modification to fit unusual cases, such as that of the river Tarim, in Chinese Turkestan, which fails to reach either sea or other river, but gradually disappears by evaporation and other causes in the great Mongolian desert; or the strange river Cassiqmare, that flows southerly out of the upper Orinoco into a tributary of the Amazon; or the dual system of the Ganges-Brahmapootra, these rivers mingling partially, but not wholly, in a single enormous delta.

In England quite usually, in America more rarely, broad tidal estuaries are considered parts of the streams, often small in size, that enter the sea at their heads. Thus we hear of the gentle little Thames being 7 miles wide at its mouth, a width that would honor the Congo. Our St. Lawrence, by this crude conception of rivers, is given a mouth quite 80 miles in width, notwithstanding that salt water predominates over the fresh scarcely more than 50 miles below Quebec. Surely the profound Saguenay, whatever its condition in former geological periods, may now claim to be a wholly independent watercourse.

River names, once well settled, can rarely be changed to conform to the natural state of things. Our maps must continue to show Minneapolis and New Orleans on the banks of the same stream, and to represent the Danube as rising in the Black Forest of Germany, whereas its most voluminous headstream, the Inn, takes rise on the borders of Italy, west of the Austrian Tyrol. If the method of following the principal water with the river name was generally applied, Europe would have no Rhinefall, as the Aare, the Rhine's greatest headstream, does not pass Schaffhausen, but rises in the Bernese Alps, to flow westward through Interlaken. The great Niger, too, would have to be rechristened hardly more than 300 miles from the sea, as the long river that sweeps in a semi-circular course through the arid sub-Sahara, and witnesses the social festivities of Timbuktu, contains a less average flow than the much shorter Benue. It is undoubtedly pleasant to behold a river wriggling extensively over the map, so we may partially excuse the geographers for calling the Volga the largest river in Europe, when, by reason of the comparatively slight precipitation, its flow is really 30 per cent inferior to that of the Danube.

A few rivers and lakes lose prestige from the unfortunate method of calling their different sections by different names, among them the St. Lawrence and Mackenzie. In fact, we rarely class the Nelson among the world's greatest rivers at all, solely because its longest and greatest headstream is called the Saskatchewan. Again, simply because the world's greatest fresh water lake narrows in its central part to a width of 5 miles or so, we are constrained by custom to call one end of it Michigan and the other end Huron. Lake Winnipeg narrows quite as much as these St. Lawrence waters, without changing its name; and, although the Straits of Mackinaw may be shoaler than the waters on either side of it, it is worthy of note that the two profoundly deep ends of Lake Baikal in Siberia are clearly separated by a submerged ridge.

Owing to the rapidly growing importance of water power, great cataracts, cascades and rapids now receive more careful attention than other river features. Evidently the greatest body of water to make abrupt descents may be found on the Congo, below Stanley Pool. How often in recent years have writers described some fall as "greater than Niagara"! One such fall, the Paulo-Affonso of Brazil, about rivals, in volume and scenic splendor, the Shoshone Falls of Idaho. Niagara's real competitors are Victoria Falls on the Zambesi and Iguazu Falls on a branch of the Parana, each of which, during flood season, undoubtedly excels Niagara. These falls occur, however, on rivers of great fluctuation, while our St. Lawrence maintains perennially its clear and copious flow. Although Victoria Falls develops more horse-power than Niagara, largely owing to its greater height, the drainage area above it falls short of that of the St. Lawrence above Erie's outlet, while, as only the more remote Zambesi sources lie within the true tropic rain belt and the water variation exceeds 60 feet in some of the contracted gorges, the curtain of falling water, during the dry season, often becomes much thinner than that of our own deep-green cataract. A greater and little-known waterfall is found on the upper Brahmapootra. Whatever its dimensions, the reading public may expect to hear of it before many years as another "greater than Niagara."

The sixth cataract of the Nile.

Conclusions regarding the average rapidity of the world's rivers can at present only be arrived at, except in a few cases, by noting the remarks of innumerable travelers in all countries. A river's total descent may be but slightly indicative of its average speed, as the descent may take place largely near the source or at a few great falls. Such speed, too, although affecting navigation, can usually have little bearing on power development. In Europe the "arrowy Rhone" surpasses all other streams in general swiftness. In the world at large, the question remains open, indications favoring the Salwin and Mekong of Burma and Siam as the swiftest rivers of the first magnitude. Of North American rivers exceeding 500 miles in length, the Fraser, Colorado and Snake seem the most likely leaders.

In cubic contents of fresh water, the St. Lawrence, with its highly lacustrine basin, easily surpasses all other river systems. A glance at the map would indicate the Mackenzie or the Nile, with their huge lakes, as next in order. These lakes, however, are comparatively shallow, the Victoria Nyanza especially so. Bathymetrical surveys of the world's great lakes vary greatly, and all estimates must remain largely conjectural until the mean depths of the Eastern hemisphere's vast land-locked seas become more definitely ascertained. Complete knowledge of the contents of lakes would not quite settle the question, as the Amazon, although having no lakes of consequence other than those caused by riparian overflows, deserves consideration from its thousands of miles of broad waterways. So stupendous are the depths of Lake Baikal, connecting with the Yenisei; of Nyassa, draining to the Zambesi; and of Tanganyika, intermittently flowing to the Congo, that the basin of one of these rivers, although not generally lacustrine, may yet be found to most nearly approach the St. Lawrence in cubic contents of fresh water. Among the three, indications favor the Congo's priority, as to the contents of Tanganyika must be added not only those of other great yet shallower basins, but the volume of a river in itself second only to the Amazon.

No accurate list has ever been made of those fresh water lakes, scattered widely about the globe, that in depth extend below sea level. In possession of such waters the very abnormal basin of the St. Lawrence again ranks first, at least seven of its lakes, Superior, Huron, Michigan, Ontario, Champlain, George and Seneca, possessing this characteristic. In all North America we can only point definitely to four other such lakes of any importance; Managua and Nicaragua in the South, Great Bear Lake in Canada and Grand Lake in Newfoundland. Northern Europe contains, numerically, quite 80 or 90 per cent of the world's supply of such waters, mostly scattered about Great Britain and Ireland, Scandinavia and Northern Russia. These include such famous lakes as Windermere, Ullswater and Wastwater in England; Ness, Lomond and Morar in Scotland; Venern and Vettern in Sweden; Ladoga and Onega in Russia; Neagh and Erne in Ireland. No true Swiss lake possesses this characteristic, but on the Italian slope of the Alps, we find five, Garda, Como, Iseo, Lugano and Maggiore, all draining to the Po. South America has none, at least north of Patagonia; Africa may have one—Nyassa; Asia has two, Baikal and the Sea of Galilee; New Zealand may have a few, as its southern lakes possess remarkable depth, but none exist in Australia. Of the two Asiatic lakes, Baikal, notwithstanding its situation, almost in the heart of the greatest continent, sinks no less than 4,000 feet below the sea level, a vastly greater distance than any other water; while the Sea of Galilee stands alone among all true fresh water lakes in having its surface level below that of the ocean.

Let us glance at a few miscellaneous characteristics of famous rivers. Confining ourselves to the great streams, the Indus rising at an elevation of about 18,000 feet in the stupendous Himalayas, has the greatest aggregate descent, while the Volga, rising only 633 feet above the Caspian, appears to be the most sluggish. Some inferior rivers, however, descend much less than the Volga, notably the St. Johns River in Florida. The isolated Tarim of Central Asia may claim the greatest average elevation, while the Jordan, almost all below sea level, is by far the most depressed. Of the great rivers having abrupt descents toward the lower ends of their basins, the St. Lawrence, Nelson, Churchill, Fraser, Columbia, Colorado and Congo stand in a class by themselves, although innumerable smaller streams have rapids and falls toward their mouths. Conflicts between fresh water and tide are most spectacular on the Amazon and Yang-tse-Kiang. The St. Lawrence possesses the clearest water of all very great streams, a condition due to the enormous lakes, while a similar cause produces a similar effect on the Neva. The Nile flows the longest distance (1,500 miles) without receiving a tributary, and has also the longest river basin, while the basin of the Salwin is the narrowest among those of great rivers. The mighty impetuous Hwang-Ho, by far the most erratic of the world's leading waterways, and at once the great friend and dread enemy of the Chinese, has moved its mouth, not by slow degrees, but by sudden action, fully 500 miles up the coast of the Yellow Sea. Headstreams of the Yukon rise a much less distance from tidewater than those of other great rivers. The Mackenzie is the leading stream to

bear the name of an explorer. Many rivers have great variations in level, but that of 90 feet on portions of the Salwin is probably unsurpassed. A unique feature appears in the St. John River of New Brunswick, where the condition of its lower sunken valley causes its waters to extend up the parallel valleys of tributaries in a system of navigable lakes or bays that mildly suggest Norwegian fiords. It remains, however, for the little Zeta River of Montenegro to perform the strangest feat of any stream, a truly novel performance by which the waters suddenly dive underground, pass directly beneath a mountain 1,000 feet high and emerge again to daylight a few miles beyond.

Any statement as to which world-famous river is most interesting would undoubtedly be promptly challenged. Advocates would appear for the Mississippi, Nile, Rhine, Danube, Euphrates and various other streams. With due caution, however, we venture the suggestion that the least interesting very great river, topographically and historically, is the mighty Lena, meandering about the bleak plains of Northern Siberia. The greatest geographical discoveries of the future, so far as they relate to rivers, may reasonably be expected from two quarters of the globe, the first including the northerly and southerly portions of the Congo basin, the second embracing the mountainous region between the Eastern Himalayas and the valley of the Yang-tse-Kiang, where considerable portions of three great streams, the Brahmapootra, Salwin and Mekong yet remain insufficiently explored.

Equilibrium and Equilibrium Organs in Lower Animals*

The Special Sense of "Up and Down"

By Dr. W. Baunacke

In addition to the organs of sight, hearing, taste, smell, and touch, all vertebrate animals, including man, possess more complex tactile organs which control the position and direct the movement of the body. The labyrinth of the ear belongs to this class.

Similar organs, often of more primitive structure, are found in all classes of multicellular animals, but not in all species. With few exceptions the operation of these equilibrium organs is dependent upon gravitation, and they give their possessors a sense of the vertical as a fixed direction and of the position of the body with respect to that line of reference. The manner in which this task is performed depends upon the structure of the organ, which varies greatly in different classes, genera, even species of invertebrates, in which the organs do not, as in vertebrates, represent successive stages in a common evolutionary series, but are rather convergence structures, which lack a common morphological origin, although they perform similar functions.

Yet there is a fundamental type, the statocyst (Fig. 1), a globular vesicle filled with a watery fluid, called endolymph, and containing one or more unattached solid

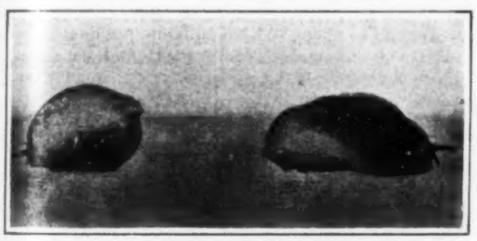


Fig. 2.—Inverted snails righting themselves

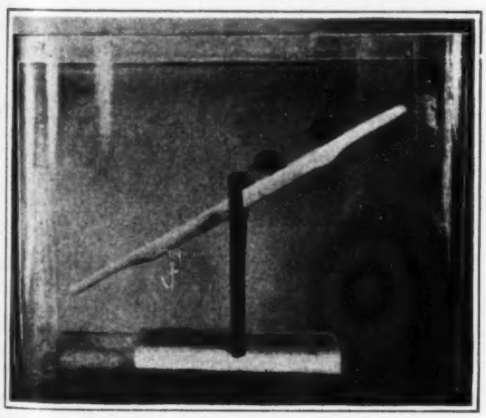


Fig. 3.—Land snails ascending a see-saw in water.

particles. These particles, or statoliths, are either calcareous concretions formed inside the body, or grains of sand or other foreign matter of external origin. As the body moves, the statolith continually seeks the lowest part of the cavity, and in so doing impresses upon the nerve cells of the wall of the statocyst stimuli which are transmitted to the central nervous system and evoke motor impulses corresponding to the actual position of the body.

These organs were regarded as organs of hearing, and were called otocysts and otoliths, until it was proved by ingenious experiments that the reactions of these animals to sounds are reflex movements of flight, caused by feeling, not hearing, the vibration of the surrounding medium. Subsequently it was shown that sense organs of this type exert an immediate effect upon muscular tension, and that the movement of the statolith with each change of position produces, in the nerve cells of the statocyst, varying contact stimuli, which cause the legs, wings or fins to move so as to maintain or restore the equilibrium of the body. All organs of this character, therefore, are classed as equilibrium organs.

* Adapted from *Die Umschau*.

The sieve-like perforations found in the water scorpion (*Nepa cinerea*) and some other aquatic insects, which

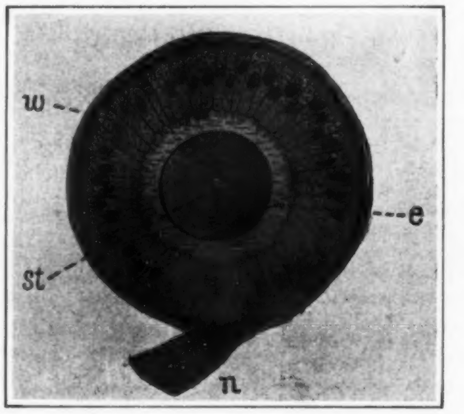


Fig. 1.—Statocyst of fresh-water mussel.
st, statolyth; *w*, nerve-cells; *e*, endolymph; *n*, nerve.

formerly were assumed to be respiratory organs, have been proved by experiment and anatomical research to be sense organs, which enable the animal to direct its course when crawling under water. This was the first discovery, in insects, of organs of equilibrium such as had been observed in representatives of all other classes of multicellular animals. These organs of the water scorpion, however, differ greatly from the typical static or equilibrium organ, the statocyst. In the water scorpion the stimulus is determined by the movement of a lighter body, air, through a heavier medium, water. Furthermore, the function of the insect organ is not to maintain equilibrium, but to cause, in definite external conditions, definite movements of the whole body, which are of great biological importance. These movements are negatively geotactic, i. e., they are directed away from the earth's center.

The question arises whether this geotactic function of static sense organs is not more widely extended in the animal kingdom, especially as the existence of statocysts in many animals is not explained by their equilibrium function.

The equilibrium of many of these animals is maintained automatically by the distribution of masses and densities through the body, while other forms exhibit an almost indifferent equilibrium. Statocysts and similar organs can act as equilibrium organs only in animals whose equilibrium is naturally unstable. This is the case in running, flying and swimming animals, insofar as their equilibrium is not maintained automatically by their structure. Hence the statocysts found in numerous animals of stable or indifferent equilibrium must have another function. The well developed statocysts of animals that crawl and burrow in the earth have been especially puzzling.

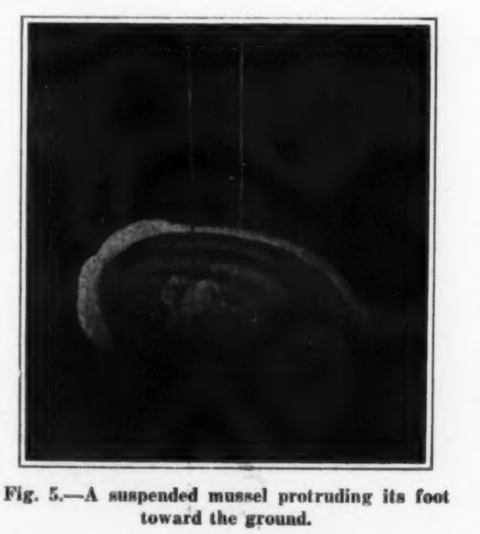


Fig. 5.—A suspended mussel protruding its foot toward the ground.

The equilibrium of the water scorpion, in water, is maintained automatically by the distribution of the reserve store of air beneath the wings. Here the negative geotactic function of the statocyst impels the animal, which seeks its food under water but is unable to rise directly when its air supply is exhausted, to reach the surface by climbing the stalk of a plant or crawling up the sloping bank. This is proved by the failure of the geotactic reaction when the statocyst is destroyed.

The burrowing movements of certain marine worms have lately been recognized as positive geotactic flight-reflexes, originating in their statocysts and failing when these organs are removed. The pecten mussel possesses

Fig. 4.—Submerged land slugs escaping from the water.

symmetrically arranged statocysts, which maintain equilibrium in swimming and also, by reflex action, cause the animal to right itself when it is inverted.

Close study of our common land and fresh water mollusks reveals characteristic reactions which prove the possession of a strong power of orientation in a definite direction, determined by the conditions of life. When a snail (*Arion* or *Limax*) is placed on its back it turns its head into the normal crawling position, brings it into contact with the ground, and by crawling forward gradually brings the rest of the body into the erect position (Fig. 2). But this reflex turning movement does not occur if the foot of the inverted snail is in contact with any object along which the animal can (and does) crawl, without regard to its position in space. Hence the reflex is evoked by the freedom of the foot and inhibited by its contact with any object. It has been proved by experiment that this reflex is not caused by the ordinary sense of touch, or by the sense of taste, smell, or sight, for it persists when these senses are destroyed. When a snail is cut in two, however, the reflex persists, in weakened form, in that part which contains the statocysts and the nerve centers associated with them. A fairly long head segment of *Limax* promptly

turns over when it is laid on its back, and a body, decapitated in such manner that it retains the brain and statocysts, exhibits the same reflex for weeks. The turning reflex, therefore, may be regarded as a function of the statocysts.

Definitely directed movements also play a great part in the life of terrestrial and aquatic mollusks. Aquatic pulmonate snails seek food under water but come to the surface for air, and some branchiate snails and mussels oscillate between greater and less depths for the same reasons, while land snails and slugs, when submerged in water, promptly make their escape if they can (Fig. 4).

A terrarium can be rid of infesting snails very quickly by immersing it in water. Land snails placed on a seesaw under water always crawl upward, reversing their motion with each oscillation (Fig. 3). They exhibit the same negative geotactic reaction in other liquids and gases. The reflex, therefore, is evoked by need of air. In *Limax* the reaction is not essentially altered by removing all sense organs except the statocysts, and the reflex persists in a severed segment that contains the statocysts and nerve ganglia. Hence the statocysts produce a negative geotactic reflex action in addition to the turning reflex. The biological importance of this reflex of flight from impending asphyxiation need not be emphasized.

Fresh water mussels exhibit positive geotactic reactions. The essentially geotactic character of the movements of the thick muscular foot, by means of which the animal buries itself in the pond or river bed, can be proved by suspending a mussel by cords in the water of an aquarium. The protruded foot always turns to the bottom, even when the mussel is suspended in a position that makes this action very difficult (Fig. 5). Here, as in burrowing marine animals, the reflex appears to be evoked by exposure and inhibited by the resistance which the foot encounters at a certain depth in the sand. The positive geotactic movements of these mussels are shown also by their burrows, always directed toward the deepest points in ponds that had been previously drained.

Our general conclusion, therefore, is that static sense organs influence the motor mechanism in such a manner as to produce and to maintain, permanently or temporarily, in a state of rest or of locomotion, a definite bodily position, which may be one of unstable equilibrium. They may cause positive or negative geotactic movements, reflex righting of the inverted body and various other effects, but their presence in an animal always indicates a need of definite orientation determined by the definite conditions of existence. The faculty of orientation may be well developed, however, in an animal destitute of special static organs, for the functions of these may be performed by almost any other sense organs. This fact greatly increases the difficulty of determining the action of the statocysts by experiment, in species from which the statocysts cannot be removed, and in which no conclusions can be drawn from exceptional cases.

The Wastefulness of Coke Ovens*

How They Can Advantageously Be Worked in Conjunction With Blast Furnaces

By Heinrich J. Freyn

The evidence of statistical investigations made by E. W. Parker of the United States Geological Survey, is that only approximately 25 per cent of the total coke produced in this country in 1912 was made in by-product coke ovens, whereas 75 per cent was produced in beehive ovens. This entailed the enormous loss of over $80,000,000 in non-recovered by-products, such as gas, tar and ammonia, without considering the substantial loss due to the non-recovery of benzol from the coal.

BLAST FURNACE AS A SLAGGING GAS PRODUCER.

By taking advantage of the recent innovation of H. A. Brassert, blast furnaces are now able to insure fulfillment of a contract for the delivery of a specified uniform amount of power in times of business depression as well as activity. Brassert virtually transforms a non-active blast furnace into a huge gas producer, and gasifies in it, small coke, raw coal, and coke breeze, on the principle of a slagging type of producer, using open-hearth slag as flux. This has been very successfully demonstrated at South Chicago and Gary. This disposes of the argument that curtailment of pig iron and coke production in times of business depression militates against maintaining, say, a gas-driven electric power plant.

In order to show what can be accomplished in the practical utilization of the surplus gases of a blast furnace and coke-oven plant of modern size, the following calculations are made:

Two isolated blast furnaces, of 350 and 450 tons daily capacity each, are installed near a large city, together with a coke-oven plant of just sufficient size to furnish the necessary coke for these blast furnaces. Coking coals of proper quality for making good blast-furnace coke can be delivered for $3 per long ton f.o.b. the furnace plant. The by-product coke is charged to the blast furnaces at $4.25 per net ton, which price is about $1.25 below the cost of standard beehive coke delivered in that locality. Coke-oven gas of a heating value of 550 B.t.u. per cubic foot, but not subject to minimum candle-power specifications, can be used in the city for domestic purposes and would bring a price of 12 cents per 1,000 cubic feet. The prevailing cost of electric power is 1.2 cents per kilowatt-hour, distributed. With a practically unlimited power market, the total surplus from the blast furnace and coke-oven gases of this plant can be absorbed by the established electric power company, which operates steam turbine power stations of approximately 300,000,000 kilowatt-hours total output per year generated at a yearly use factor of about 38 per cent.

With such favorable local conditions, the total quantity of coke-oven gas can be used for domestic or power purposes, or both. To realize this, gas from some outside source must be used for under-firing at the coke ovens. Blast-furnace gas should not be used for this purpose in this instance, since this ideal gas-engine fuel can much more profitably be utilized for the production of electric power. Producer gas made from small coke and coke breeze in revolving grate or slagging type gas producers would answer splendidly and should be used if sufficient quantities of these fuels are available. As a general rule, however, the amount of coke breeze does not exceed 7 per cent. to 8 per cent. of the total coke made, and this quantity is not sufficient to produce the necessary gas for under-firing. In this discussion, it was assumed that a mixture of raw coal and coke breeze is gasified in some type of mechanically-stirred gas producer equipped with apparatus for the recovery of by-products. This producer plant would be in operation at practically full output at all times, making this method of providing for under-firing very cheap and attractive. The question whether the total quantity of coke-oven gas produced should be marketed for community use, or only its rich portion, while the lean portion is used for power purposes in the natural state, or in admixture with blast-furnace gas, can be properly answered only when the quality of the coking coals is known and when the value of the coke-oven gas is correctly appraised.

POSITION OF THE COKE-OVEN GAS ENGINE.

The blast-furnace gas engine has to-day attained a very high standard, as can readily be seen by the truly remarkable results achieved with the world's largest gas-engine plant at Gary; but the coke-oven gas engine, although mechanically equivalent to the blast-furnace gas engine, has to deal with a fuel of entirely different character. The large percentage of hydrogen in coke-oven gas causes an extremely rapid flame propagation, so that the time of combustion of a mixture of coke-oven gas and air is considerably shorter, and this combustion much more of an explosive character, than is the case with blast-furnace gas. The compression in coke-oven gas engines must, on account of these characteristic qualities of the fuel, be kept considerably lower than is customary and appropriate for blast-furnace gas engines. Costly experience has taught European gas-engine manufacturers to reduce the compression pressure in coke-oven gas engines to 110, and even to 85 pounds per square inch, depending somewhat on the percentage of hydrogen in the gas.

Owing to the snappy action of the gas, coke-oven gas engines are at times quite susceptible to back-firing and premature explosions. Effective cooling of gas cylinders, pistons, piston rods, etc., becomes, therefore, a very important matter on account of the intense heating of these parts. The absolute quantities of coke-oven gas consumed during one working cycle are comparatively small, even at full load, and perfect regulation of coke-oven gas engines is, therefore, not so easily accomplished as that of blast-furnace gas engines. Serious difficulties were encountered in the earlier days because it was found quite impossible to maintain satisfactory parallel operation, especially at fractional loads, on coke-oven gas-engine generators feeding into the same system. Ignorance on the designer's part was very largely responsible for these difficulties because gas ports and gas-valve areas were made far too large, and entirely out of proportion to the size of the air ports, since no attention was paid to the low specific gravity of coke-oven gas. Much larger quantities of gas than actually required at any specific load were thus caused to enter the gas cylinders, and these earlier engines nearly always operated on excessively rich mixtures. The obvious result was, after burning, destruction of exhaust valves, piston rods, and cylinders, violent back-fires and vicious premature explosions, all of which caused extremely unsatisfactory commercial operation.

To-day, the coke-oven gas engine has reached such a high state of perfection in Germany that it is second only to the blast-furnace gas engine in importance and serviceableness, with the qualification, however, that unit capacity and more particularly the rating must be conservative.

The latest coke-oven gas engines installed at Bonifacius colliery in Westphalia, are of the twin-tandem, double-acting, four-cycle type having four gas cylinders 47½ inches in diameter, 51 inch stroke, and develop at 94 revolutions per minute about 5,000 b.h.p. Parallel operation is beyond criticism, and the load factor of these engines is very high—from 90 to 100 per cent—since peak loads are taken up by the blast-furnace gas-engine plant and the steam turbines. These engines were built two years ago and are probably the largest coke-oven gas engines in the world. The compression pressure is only 85 pounds and the maximum explosion pressure does not exceed 250 pounds per square inch. Each cylinder end is provided with three igniters. The gas consumption as measured by means of a large gas holder was found to be 12,000 B.t.u. per kilowatt-hour at 90 to 100 per cent load. The over-all mechanical efficiency, including generator, is 82.3 per cent at that load.

The overwhelming majority of gas-engine manufacturers in this country restrict the capacity of coke-oven gas engines to about 700 or 750 b.h.p. per double-acting cylinder at present. This prudent and conservative policy on the part of American gas-engine builders shows excellent judgment. The coke-producing industries should encourage this spirit and assist the manufacturers by installing coke-oven gas engines to about 700 or 850 b.h.p. per double-acting cylinder.

It should be remembered that the presence of sulphur in coke-oven gas in the form of sulphuretted hydrogen and carbon bisulphide was the cause of very serious troubles before it was learned how to combat its influence. The slightest water leak in the gas cylinders from defective pistons or water-cooled exhaust valves resulted in serious corrosion of all finished parts, and particularly of piston rings, piston rods, and metallic packing. This cor osion was caused by sulphuric acid formed by the combination with oxygen and water of sulphur dioxide, resulting from the combustion of sulphur in the gas. Instead of striking at the root of the evil by proper sulphur purification, and by prevention of water leaks, attempt was made to cure the trouble by resorting to building materials which would not be attacked by sulphuric acid.

Considerable progress has been made in recent years in design ng sulphur cleaning plants which eliminate nearly all of the sulphuretted hydrogen, although no practical means has so far been discovered to separate carbon bisulphide from the gas. Gas-engine manufacturers in Europe are, however, willing to guarantee satisfactory and continuous operation of gas engines supplied with purified coke-oven gas containing as much as 1.25 grammes of sulphur compounds in one cubic foot.

Naphthalene which is deposited by the gas, particularly in cold weather, easily obstructs pipe lines and valves. This also has been the cause of much annoyance. If benzol is recovered from the gas, no trouble from naphthalene deposits can occur, since it is absolutely necessary for efficient benzol recovery to extract the naphthalene from the gas. In plants where benzol is not recovered, it happens not infrequently that the gas pipes, etc., have to be steamed out from time to time in order to dissolve the naphthalene, which otherwise accumulates in the piping and on the valves, until the output of the power plant is noticeably reduced. Incidentally benzol recovery, in connection with by-product coke-oven plants, improves gas-engine operation owing to the elimination of certain hydrocarbons, and because the heating value of the gas is reduced about 5 per cent. Coke-oven gas used for power purposes, or as fuel in a steel plant, does not require any illuminating properties; the recovery of the benzol from the gas for sale offers very attractive financial possibilities, and yields an exceptionally handsome profit on the investment.

A straight-forward acknowledgment of the salient

*Extracts from a paper read at the New York meeting of the American Institute of Mining Engineers, February 18th, 1914, and published in *The Iron Age*.

difficulties with earlier coke-oven gas engines coupled with an account of the remedies which eliminated the trouble in subsequent installations can only have a beneficial effect upon the cause of the coke-oven gas engine. The meager experiences had with one or two earlier coke-oven gas-engine installations in this country are in the author's judgment not sufficient premises to argue for or against the use of coke-oven gas for gas-engine purposes and to draw conclusions of any value.

DIRECT-MILL DRIVING WITH GAS ENGINE.

The application of the coke-oven gas engine for direct driving of rolling mills is to the author's knowledge not illustrated by a single installation abroad or in this country. Its absence from this field is largely explained by the geographical separation of coke-oven plants and rolling mills. The load conditions of rod, wire, and sheet mills are not unfavorable for direct gas-engine drives, since they impose upon the prime mover neither violent nor excessive load variations. The average power demand of such mills is moderate, so that frequently single tandem gas-engine units are fully capable of performing the work. The direct-connected rolling-mill gas engine for light continuous mills does not require much overload capacity, and can therefore be suitably rated to operate at a high load factor. The gas consumption is then very low and the thermal efficiency high. The result is a substantial fuel economy per ton of finished product, compared with steam engine, steam turbine, or electric-motor drives.

The principal advantage of direct gas-engine mill drives is, of course, the saving in cost of installation and operation. Such direct drives do away with costly combinations of electric central station, transformers, transmission lines, mill motors and the requisite expensive auxiliaries. They are, moreover, not attended by the multiplicity of efficiency losses on account of the roundabout way of generation, transformation and transmission of energy, which are handicapping electric mill drives.

In our country the installation of by-product coke-oven plants located near blast furnaces and steel mills is rapidly becoming distinctly American practice. Blast-furnace gas of low heating value and great volume does not lend itself readily to economical long-distance transportation through pipe lines, because the first cost of compressor equipment and pipe line would alone be prohibitive, but the transmission of coke-oven gas for illuminating purposes through distances of 30 and 40 miles is not unknown in this country, and the expenses incidental to the installation and operation of booster stations are moderate.

EMPLOYING GAS MIXTURES IN ENGINES.

No matter what objections could justly or unjustly be raised against the use of coke-oven gas for direct power generation in modern gas engines, none of these can possibly apply on the use of a mixture of blast-furnace and coke-oven gas. The practice of combining blast furnaces, steel mills, and coke-oven plants in one locality, gives the American iron and steel master an enormous advantage over the majority of his European competitors in the matter of rational utilization of the available surplus gases. It is evident what truly ideal conditions would obtain in such combined plants if only one kind of gas fuel were used for all requirements of the plant. A gas mixture in suitable proportions of blast-furnace and coke-oven gas would fulfill the most exacting specifications which could be imposed.

There would not be any difficulty in maintaining a heating value of the gas mixture to all intents and purposes uniform, if this task were committed to the action of automatic devices. One, or if necessary, several automatic recording gas calorimeters—for instance of the Smith type—could be equipped with a maximum-minimum electric-contact attachment, corresponding to the permissible maximum and minimum heating value of the gas mixture. These calorimeters would control—by means of relays and electric motors—gate or butterfly valves, arranged in the coke-oven gas pipe at, or near, the point of connection with the blast-furnace gas main. The suggestion of using a gas mixture for gas-engine purposes is by no means new or original, with the exception perhaps of the proposed method of controlling the heating value automatically. Gas-engine plants using such mixtures have been in very successful operation abroad for a number of years. A mixture of one part of coke-oven gas of 500 B.t.u. and of 15 parts of blast-furnace gas of 100 B.t.u. would have a heating value of 125 B.t.u. per cubic foot.

The fact that the gas mixture is supplied by two practically independent sources constitutes in itself a safety factor of no little value. At times of momentary shortage of either ingredient, the regular output of electric power would be maintained by admitting to the engines a mixture leaner or richer than standard. The possibility of using, in the engines, producer-gas made by one of the existing blast furnaces operating according to Brassert's gas-producer principle is an adequate safeguard against the influence of a curtailment of pig iron and consequently blast-furnace gas production brought about by a business depression. Blast-furnace producer-gas has about the same heating value as the gas mixture, and its composition by volume is approximately as follows:

BLAST-FURNACE PRODUCER-GAS.

	Per cent
CO	34.0
CO_2	1.6
H	2.9
CH_4	1.0
B.T.U.	126

The percentage of hydrogen in furnace producer-gas is considerably smaller than in the standard gas mixture. The former gas can, therefore, be substituted for the mixture with impunity. The higher percentage of carbon monoxide in the producer-gas will counter-balance the reduction in hydrogen to a large extent, as far as the effect upon gas-engine operation is concerned. It can thus be expected that the change from one gas to the other can be made, even without important readjustments of valve and damper setting on the gas engines.

The Eclipse of the Sun and Electric Waves

The Committee for Radio-telegraphic Investigation of the British Association for the Advancement of Science has issued the following note regarding a special investigation which it proposes shall be carried out with the object of studying the effect on the propagation of electric waves of the total eclipse of the sun on August 21st next:

The forthcoming total eclipse of the sun affords an exceptional and important opportunity of adding to existing knowledge of the propagation of electric waves through air in sunlight and in darkness, and across the boundaries of illuminated and unilluminated regions. The eclipse will be total along a strip extending from Greenland across Norway, Sweden, Russia and Persia to the mouths of the Indus. In Russia the duration of totality will be a little more than two minutes.

There are two main points calling for investigation during the eclipse. In the first place, the propagation of signal-bearing waves through air in the umbra and penumbra will probably obey laws different as regard absorption and refraction from those obeyed in illuminated air. In the second place, the strength, frequency and character of natural electric waves, and of atmospheric discharges, may vary. The variations may occur either because the propagation of natural waves from distant sources is facilitated or impeded by the eclipse, or, possibly, because the production of natural electric waves or atmospheric discharges is for some unknown reason affected by the eclipse.

These points have previously been investigated to only a slight extent. The observers of signals, during the solar eclipse of April 17th, 1912, nearly all agreed that the strength of the signals was greater during the eclipse than an hour before or after. There was only one special observation of strays during the same eclipse, when very pronounced and remarkable variations were recorded during the passage of the shadow-cone across Europe.

To investigate the propagation of signals across the umbra, it will be necessary to arrange for wireless telegraph stations on either side of the central line of the eclipse to transmit signals at intervals while the umbra passes between them. This transit of the umbra occupies about two minutes. It is thus very desirable that the Scandinavian and Russian stations should transmit frequently throughout several minutes before, during and after totality. But stations other than those favored by their proximity to the central line should endeavor to keep a complete record of the variations of signals during the eclipse. Stations in Europe west of the central line and stations in the Mediterranean and in Asia Minor may find noticeable changes in the strength of signals, particularly long distance signals, between the hours of 10 A. M. and 3 P. M., Greenwich time; and it is probable that the stations of India and East Africa, and ships in the Indian Ocean, may feel the effect of the penumbra in the afternoon. On the other hand, ships in the Atlantic, and fixed stations in Eastern Canada and the United States, will probably be affected by the penumbra in the early morning. At Montreal the eclipse—partial—is at its greatest phase at 5:52 A. M. Standard Time. It is possible that the eclipse may have some influence even when it is invisible.

The investigation of strays is of as great interest as that of signals. So far as is yet known, the natural electric waves reaching wireless telegraph stations in latitudes higher than 50 degrees appear to travel mostly from the South. Thus the greatest changes produced in strays by the eclipse will probably be experienced at stations in Scandinavia and Russia, to reach which the waves must cross the path of the umbra. At the same time changes of some kind are to be expected in other districts than these, and it is therefore desirable that statistical observations of natural electric waves be made all over the world, and especially at places within an earth quadrant of Southern Russia. It is also desirable that meteorological observations, including those of atmospheric ionization and potential gradient should be at the disposal of the committee when considering the records of strays and signals.

The committee proposes to prepare and circulate special forms for the collection of statistics of signals and strays, especially within the hemisphere likely to be affected by the eclipse; it will endeavor to make provision for the transmission of special signals at times to be indicated on the forms; and it will offer for the consideration of the authorities controlling stations near the central line a simple programme of work. The discussion of the observations, and the comparison with meteorological data, will be carried out by the committee; and digests of the statistics, together with the conclusions drawn from the analysis, will be published in due course.

The committee would be greatly aided in the organization of this investigation if those possessing the necessary facilities and willing to make observations during the eclipse would communicate with the honorable secretary, Dr. W. Eccles, University College, London, W. C., at the earliest possible date.

Athletic Sports in Relation to Health

It is strange that the problems of athletics rarely receive the attention of those who are most concerned with health, the supposed purpose of bodily exercise. The management of athletics is rarely found in the hands of a physician, by whose scientific guidance the various sports would be freed from the dangers attending some of the present athletic practices. Athletics have for the most part to-day become the province of the people at large. It is the trainer rather than the physician, the hero-worshiper rather than the hygienist, who directs and inspires physical exercises which ought to be undertaken primarily in the interests of a sound body and a sound mind. Games have developed into contests in which victory is sought at any human price. The "manager" is the foremost adviser, and the physician is called on as a last resource to mend the damage that may have been done in an ill-advised struggle for athletic supremacy. Until there is wide-spread education as to the proper purpose of bodily exercise and the dangers that beset the indiscriminate and uncontrolled pursuit of athletics by every one whom the inclination stirs, it is a seemingly hopeless task to preach the gospel of reform.

Meanwhile the physician must develop sound judgment and sane advice. Only the beginnings have been made in this field of study. If football or rowing or bicycling have their dangers, what are they? These questions demand answers. Among the internal organs the heart and kidneys have hitherto received most consideration in connection with the physiology of exercise. There is an idea abroad that each form of athletics has its own peculiar type of defects. Just as one hears of the "tobacco heart," there are the alleged "bicycle heart," "football kidney," etc. This is not true. The results of athletic exercise may vary in degree but not in kind. Athletic exercises may be divided into feats of strength and feats of endurance. These do not differ essentially in their effect on the body. There are no important differences between the different types of athletic sports in respect to their physiologic effects on the body. The severe symptoms, however, make their appearance more prominently in sports like football, wrestling, bicycle contests, etc., which may call for extreme exertion. To what degree the distinctly harmful results of improper athletics may arise depends on a variety of circumstances. Age is a factor of significance. During the period of boyhood, when the organs have not reached their full development, the person is unusually sensitive to muscular excesses. "Constitution" expresses in a somewhat vague way another factor which determines the fitness of a person for athletics. There must be adequate development, suitable nutrition and a competent nervous system, the latter element often being undervalued. Obviously, appropriate training furnishes another safeguard against the dangers of athletic overdoing. Much that is called "training" in this country is, however, a combination of unscientific and sometimes irrational dietetics. Last, but not least, the degree of exertion required is a feature of determining significance when the ill effects of athletic sports are to be avoided. The distinction between doing and overdoing, says *The Journal of the American Medical Association*, needs to be learned and appreciated more than any other single factor in the rational pursuit of bodily exercise for health and enjoyment, rather than for personal superiority and group supremacy.

Liquid Crystals

Their Paradoxical Nature and Life-like Properties

Most of what we know about that seeming paradox—liquid crystals—we owe to the labors of Prof. O. Lehmann. The article which we publish here is, for the most part, a translation of an article from the pen of Prof. Lehmann as it originally appeared in Prometheus. To this has been added information gathered from the Annalen der Physik, from the Proceedings of the Heidelberg Academy of Science, and from Die Umschau.—ED.

WHEN in spring all nature begins to teem with life and growth, our wonder is ever aroused anew, and we begin to speculate over the differences of organic and inorganic matter; the chemical elements of the two are identical, yet we cannot imagine any artificial combination resulting in a substance capable of growth, reproduction, sensation and teleological action. Matter as soon as it is living seems to slough off the stern laws of physics and chemistry—a fact which Aristotle explained to his generation by the assumption of a new force—"Teleology."

For the present-day students of nature a mere name is not enough, they are driven to examine with exactitude just how living matter differs from inert matter, and to create forms simulating living organisms, however simple, in order to prove in what respects and how far these fall short of possessing life.

Figs. 1 and 2.—Coalescence (flowing together) of two crystals of ammonium oleate.

This is no simple task since the peculiarities of the composition of matter are too little understood and there is scarcely an analogy between the realm of life and that of physics or chemistry. Nothing but the growth of crystals admits of any comparison with the growth of organisms, and even here the supreme difference exists that crystals always arise from a solution, whereas the substance of living organisms is insoluble, as witness the animated drop of albumen, the amœba.

I was always dissatisfied with the attitude of mind that regarded this analogy as purely superficial without further probing, and my efforts were early directed to the thorough investigation of the growth of crystals and to a search for further analogies.

I began with the construction of a crystallization microscope furnished with hot and cold stages, which allowed me to follow the formation and dissolution of the most minute crystals. What I saw was more than I had dreamed, a wonder-world made up of water-clear or most highly colored brilliants, and not dead, but apparently alive, reacting to every change of temperature by growth and dissolution of these crystals, sometimes one set of forms greedily devouring another, and these later turning on their devourers. Invisible forces seemed to be piling up the tiniest building stones into regular, transparent structures, and then pulling them down again.

According to the molecular theory, the molecules themselves are in a state of constant rapid motion, and impelled by a mutual attraction which reminds us of magnetism, arrange themselves in crystals of mathematically exact form.

In case of melting, according to an old and still very generally accepted theory, this attractive force becomes so small that the crystalline arrangement ceases to exist and the molecules again move perfectly freely among themselves. Conversely with solidification, the molecules are assumed to snap back into such an arrangement that free movement among themselves and fluidity of the mass are instantly excluded.

Since the molecules themselves are not supposed to change, but only the manner of their aggregation to vary, I am accustomed to call this theory "The Theory of Identity." If crystallization and solidification are two terms for one and the same process, then the existence of liquid crystals is unthinkable. If in case of over-cooling of a molten masss, the irregular arrangement of the molecules persists, then according to this theory an amorphous mass of such origin cannot be reckoned among the solid bodies. The frequently observed appearance of two or more crystals of different form in the same molten mass (polymorphous modifications)

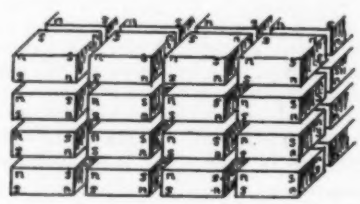
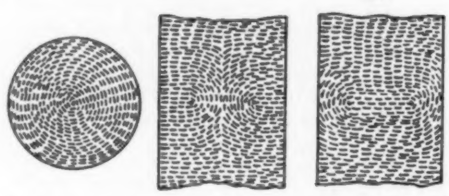


Fig. 3.—Magnetic model analogous to the process shown in Fig. 1.



Figs. 7 to 9.—Examples of the structure of liquid crystals.

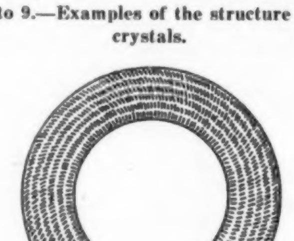
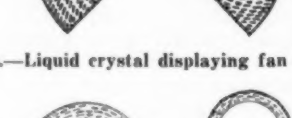


Fig. 10.—Liquid crystal displaying fan structure.



Figs. 11 and 12.—Structure of liquid spherocrystals and crystalline froth.

would be explained by saying that molecules of one and the same form side by side arrange themselves in different crystalline forms, while the transformation of one crystalline form into another were prevented through the overcrowding of internal friction.

If such a transition occurs, in one case through elevation and in another through depression of temperature, then the temperature limits must differ according to the amount of internal friction.

To my surprise I found in the case of one of the first substances I investigated ammonium nitrate, a condition which could not be explained by this theory. The very soft, regular modification crystallizing at 161 degrees, crystallized a second time at 125.6 degrees, giving a somewhat firmer tetragonal modification. This crystallized again at 82.8 into still firmer needle form, this again at 32.4 degrees to a rhombic form, and this finally at —16 degrees to a tetragonal form much harder than that between 125.6 degrees and 82.8 degrees.

By raising the temperature we get again at —16 degrees the firm rhombic form, at 32.4 degrees the needles, at 82.8 degrees the tetragonal form, at 125.6 degrees the regular form, until finally at 161 degrees we obtain again the usual amorphous completely fluid mass.

In contradiction to the "Theory of Identity"

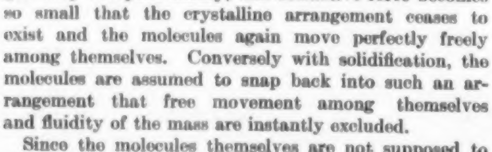
Figs. 4 to 6.—Different orientation of two molecules in liquid crystals.

there exists for each transformation one transformation temperature, and this temperature is constant for the transitions back and forth. This appears analogous to the dissociation temperatures of water containing salts, which led to the conclusion that polymorphous transformations are at base dissociation phenomena, and not simple molecular rearrangement.

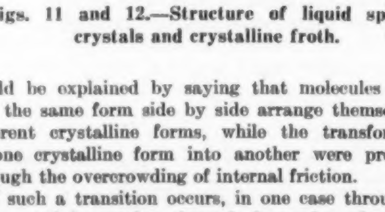
In complete contradiction to the "Theory of Identity" is the further fact that the properties of polymorphous modifications, especially their solubilities, are different, as is the case with salts containing different amounts of water of crystallization.

For instance, one is more soluble above, another below, the transition temperature. Given a saturated solution of the less soluble, this constantly increases, eating up the more soluble which goes into solution. Were the old "Theory of Identity" correct. similar phenomena (one form preying upon another) would occur with bent crystals at the spots where the crystalline structure is disturbed by the bending. Already observations on the flow of crystalline glacier ice and of crystalline metals, as lead, under high pressure, had shown that their properties remained unchanged. The "Theory of Identity" was obliged to assume that the plasticity of the crystals was only an apparent one, depending on fracture followed by re-welding of fragments, and that the structure of each separate fragment was entirely undisturbed. My observations on ammonium nitrate are a complete contradiction of this assumption, since I found that the crystals appearing at the higher temperatures might, without harming their transparency, be bent into rings in which structure is changed. Thus the fragments must be separate molecules—the crystal formation was actually changed—while the properties remained constant. This means the destruction of the "Theory of Identity."

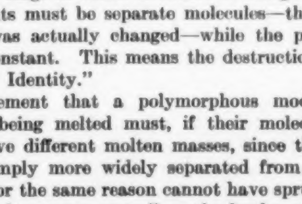
The statement that a polymorphous modification capable of being melted must, if their molecules are different, give different molten masses, since the molecules are simply more widely separated from one another, and for the same reason cannot have sprung from the same molten mass, as well as the further statement that the characteristic properties of a molten mass are altered by solidification, although we have to do



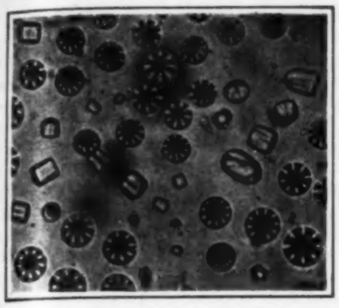
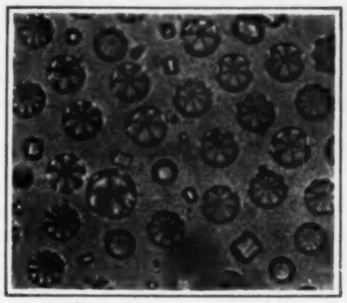
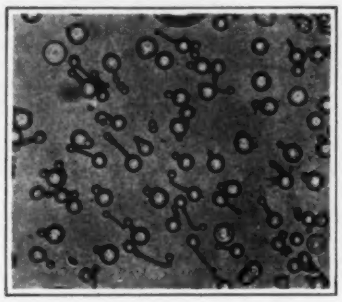
Figs. 13 to 16.—Effects of surface-tension of the mother-liquor upon the structure of liquid crystals.



Figs. 17 to 22.—Disturbances produced in liquid crystals by non-isomorphous admixtures.



Figs. 23 to 25.—Myeline forms.


Figs. 26 to 31 show a number of views of seemingly living crystals of para-azo-acetic acid ethyl ester crystallized from monobrom naphthalene.

here only with a change in the manner of aggregation, is easy to disprove. For instance, ice molecules are different molecules from those of water; solidification is not simply a change of aggregation, but a process of crystallization from solution like any other. In the neighborhood of the freezing point water is a solution of ice in ordinary water which at the freezing point becomes saturated. The peculiar fact that water expands near the freezing point is explained by the increase of the number of ice molecules at the expense of the water molecules as the temperature sinks. Between the two kinds of molecules there exists a condition of chemical equilibrium as in other cases of association and dissociation, and yet we are not concerned with a change in the chemical formula for water, which follows Avogadro's law, but merely with a combination of molecules of salts with water of crystallization. It is possible to make a further statement. Ice vaporizes as does water. If vaporization follows the "Theory of Identity" and consists only in the increase of intermolecular space, then water-vapor and ice-vapor must be different, which is not the case. The difficulty is done away with if we reject the "Theory of Identity" and regard vapor as a special modification, the molecules of which are of a new variety; then we have the possibility of a solution of vapor in water, an assumption which seems to be borne out by the anomalies of liquids in the neighborhood of the boiling point.

Next the question will arise: Why should we have only one molten form of a substance while (for example, in the case of ammonium nitrate) we have several solid modifications?

The answer is that we may have several liquid forms. Perhaps the very soft regular form of ammonium nitrate appearing between 161 degrees and 125.6 degrees must be regarded as fluid if we are able to show that its elasticity is zero. That no one thought of this before is due to the mistaken assumption that the states of crystallization and solidification are identical.

My attention was first brought to this through the investigation of the form of silver iodide formerly considered amorphous and viscous, and which I became convinced was regularly crystalline. The proof that its elasticity is zero I was not able to adduce. The strict proof that liquid crystals actually exist I succeeded first in obtaining from ammonium-oleate hydrate. It rests on the following reasoning:

Elastic recoil can take place only when molecules are pulled or twisted out of their position of equilibrium. In the case of the above-mentioned soap crystals the molecules are movable in such a way only that when two differently oriented molecules come into very close contact they immediately assume a definite structure which may be designated as the arrangement of molecular equilibrium; compelled to the change by the elastic recoil appearing momentarily at the point of contact (this result does not follow with solid crystals on account of their rigidity) in the simplest case, entirely uniform crystalline structure, which with respect to its orientation, holds the middle ground between those of its components.

Deformation of a liquid crystal of ammonium oleate, be it much or little, and of whatever sort, was never sufficient to produce permanent elastic recoil, for broken continuity or any other disturbance of molecular structure disappears again entirely of itself, and with it all elastic tension.

Let us study the nature of liquid crystals more closely. Minute crystals of neutral ammonium oleate have the form of elongated tetragonal octahedrons, with rounded edges and curved planes.

The relation of the molecules in case of fusion of two crystals may best be explained by a comparison. (See Figs. 1 and 2.) The molecules behave as though they were the plate-like units of an astatic magnetic system, exerting a directive influence on one another, but easily movable around their optical axes only. (See Fig. 3.)

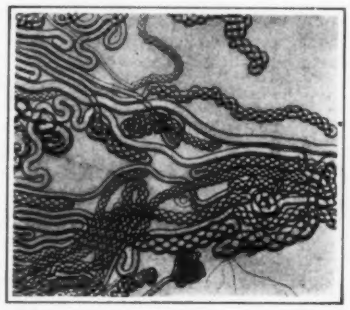
It is plain that the surfaces of these plate-like molecules will be parallel to one another, while their edges preserve no definite relations, or possibly are constantly changing their order as a result of thermic movements. Larger crystals have for this reason the form of a double cone, cross-sections being circles, not quadrilaterals as for smaller crystals.

These form a noteworthy transition from complete crystals, whose molecules have an entirely harmonious arrangement, to ordinary liquids where the arrangement is entirely irregular throughout. Such forms I have therefore named semi-isotropic liquid crystals. As remarked, the arrangement of the molecules is not always homogeneous, but sharp transitions may appear (Fig. 4) or fan-shaped transitions (Figs. 5 and 6), or radial arrangement as in spherical crystals (Fig. 6). Especially frequent are conical disturbances (Figs. 8 and 9). By bending, a fan structure may result (Fig. 10).

All these arrangements, departing more or less from the normal crystalline structure, as well as from the semi-isotropic structure, exhibit stable equilibrium of the molecules, for after not too far-reaching disturbance they return to their original form and remain constant in spite of the thermic movement of the molecules.

It would be of great interest if this stable molecular arrangement could be calculated in advance from the






Figs. 30 to 33.—Some of the phantastic shapes assumed by liquid crystals.

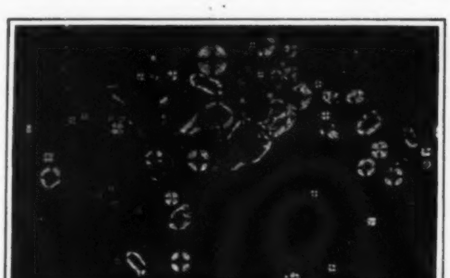


Fig. 34.—Liquid crystals found in the aorta of a rabbit in a diseased condition produced by egg-diet.

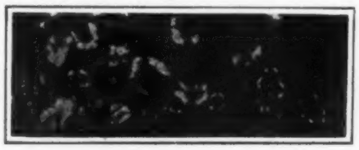


Fig. 35.—Liquid crystals found in the liver of a rabbit.

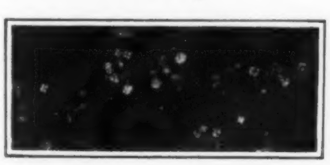


Fig. 36.—Liquid crystals in the bone marrow of a rabbit.




Figs. 37 to 40.—Knots produced by the filling out of loops.

nature of molecular forces. This has, up to the present time, been impossible on account of insufficient knowledge of these forces. Better acquaintance seems to be attainable in the future. It is possible in the case of liquid crystals as elsewhere, by means of disturbances brought about by forces of known nature and amount, to investigate the forces in question. The procedure that naturally would be tried first—i. e., mechanical deformation—appears at first glance impracticable because currents in a liquid crystalline mass do not produce disturbances, since, as before noted, through the action of molecular elasticity, the original structure is spontaneously regained. However, in case the rapidity with which the molecules glide over one another is sufficiently great, they can be moved out of their original position by mechanical force, for one sees that the optical axes, whatever their original position, now become perpendicular to the direction of push. This relation may be illustrated by a comparison. The molecules may be said to behave like the casters on a truck. These assume a position with their axes of revolution perpendicular to the direction of the push. As in the case of the truck, the resistance to the truck becomes sensibly less as soon as the readjustment of the casters has taken place, the same principle holds good for the deformation of liquid crystals. Through the rearrangement of the molecules the internal friction becomes markedly less, for the molecules behave like the casters, since they revolve most easily around axes parallel to their optical axes, and their plane surfaces are now parallel with the direction of push.

On compressing a fluid crystal mass between two glass slides, the molecules arrange themselves with their principal axes perpendicular to the glass and their surfaces parallel to it. Thus a layer of fluid becomes transparent after having been made opaque by vigorous disturbance. The adhesive force of the glass can bring about the same effect, as is very well shown by placing the mass in a capillary tube, in which case the plate-like molecules range themselves parallel to the walls, their optical axes becoming radially arranged, as is evidenced by the appearance between crossed Nicols of lines of interference parallel to the axis of the tube.

Crystal plates in place of glass can by their power of adhesion force the molecules into very definite orientation, so that not only their surfaces, but their edges as well, become parallel, and the molecular structure of the liquid crystalline layer resembles the structure of solid crystals.

In some instances the orientation of the molecules of liquid crystals may be affected by a magnetic field whose effect combines with that of the limiting plates according to the parallelogram of forces, from which it may be concluded with reference to the possibility of magnetization, that not only is the mass as a whole anisotropic, but so is every separate molecule. This would accord with the assumption that molecular forces are of magnetic nature. A layer made opaque by violent agitation can be cleared by the influence of a magnetic field, since all the molecules fall into an arrangement with their principal axes coincident with the lines of magnetic force, thus producing a homogeneous, semi-isotropic layer, which is transparent.

Surface tension also has the power to bring about molecular order, at least when it exceeds a certain degree. For example, small liquid crystals of ammonium oleate which possess uniform structure (as shown by the fact that when turned between crossed Nicols they become completely dark) show illumination in the neighborhood of the ends when through the addition of water to an alcoholic solution the surface tension is increased.

With a high degree of surface tension the plate-like molecules become parallel to the surface with their axes perpendicular to it, as illustrated by Figs. 11 and 12, which show the structure of liquid spherical crystals and foam. Many disturbances of liquid crystals which between crossed Nicols appear as bright stripes or as bright points surrounded by alternately bright and dark quadrants, are to be referred to the influence of the surface tension of fine threads of the mother liquor running through the mass. The molecules arrange themselves tangentially to these threads either in concentric circles or in hyperbolas. This pronounced departure from parallelism causes opacity in these places.

In the case of solid crystals a disturbance can be produced by a non-isomorphic admixture, and this holds true for liquid crystals, especially for the "crystal drops," whose tendency to keep their shape is so slight that surface tension reduces them to spheres, with a thread passing directly through the center. Fig. 17 shows such a drop in cross-section. The effect of the above-mentioned admixture shows itself in a bending and twisting of the threads and a warping of the molecular structure of the "crystal drops," giving in ordinary light the appearances shown in Figs. 19 and 20. Very violently twisted drops appear to consist of lamellæ of uniform thickness.

Many liquid crystals alter their firmness of texture on taking up foreign material. For example, ammonium oleate crystals fuse better when methyl or ethyl alcohol is used as a solvent than by separation out of higher alcohols. When such a mixture is made up of unequal component parts the crystals may dissolve at the center when warmed, while solid crystals melt only on the surface.

Certain mixed liquid crystals in the shape of long cylindrical threads with hemispherical ends are called myeline forms. Their structure suggests that of the spherical crystals, since the molecular axes are arranged radially around the center of every cross-section (see Fig. 23). The structure shows torsion as does that of many other mixed crystals, the threads tending to rotate around their axes. The results of rotation in myeline forms is remarkably well shown in a series of photographs.

Figs. 32 and 33, show a remarkable system of spirals thus produced. Our head-pieces and Fig. 39 show such spirals twisted into knots, and Figs. 37, 38 and 40, show simple knots resulting from the filling out of loops.

The apparently living liquid crystals are most interesting. Take, for example, those of para-azo-oxy-cinnamic acid-ethyl-ester, which crystallize out of monobromnaphthaline at the lowest possible temperature. The ball-like "crystal drops" show at some one point at least a flattening due to conical structural disturbance, at which point a swelling or pseudopodium in the shape of a cylindrical thread is pushed out, sometimes with great force when the temperature is allowed to fall, and draws back again when the temperature rises (Fig. 25). Bacteria-like rods and threads arise in the solution. With variations in temperature a snake-like motion of the latter occurs, due to rapidly succeeding uneven expansion and contraction. Frequently they are seen to draw themselves together into spheres or rosettes, or to divide like organic cells. Of special interest is a structural change arising from a conical disturbance and advancing rapidly in wave-like fashion. This change resembles the rotation of a system of stripes; "crystal drops" may thus appear like infusoria with mouth openings surrounded by wreaths of cilia in lively motion. The multiplicity of these forms is suggested by the photographs shown in Figs. 26 to 31 (apparently living crystals of para-azo-oxy-cinnamic acid crystallizing out of monobromnaphthaline).

What is the source of the energy of these movements and transformations? Probably the molecules which crystallize out of solution are widely dissociated. The process depends, then, on the formation of new molecules and the disappearance of chemical energy. The forces in action arise from a direct transformation of chemical energy into the energy of motion, hitherto seen only in the case of muscular energy, with a higher grade of working efficiency than that of thermodynamic machines, because the latter are obliged to transform chemical energy first into heat.

The circumstance that such expansile liquid crystals of cholesterin and lecithin (substances widely diffused in organisms) of albumen and hæmoglobin occur, suggests the idea that the analogy between the phenomena of growth and motion of the apparently living crystals and living organisms is one of profound meaning.

W. W. Weinberg, in an article on liquid crystals in disease, gives some interesting illustrations of cholesterin crystals. Fig. 34 shows various forms of liquid crystals in the aorta of a rabbit fed on cholesterin-containing food—egg yolk. These crystals form plaques entirely analogous to those occurring in human beings in arteriosclerosis. Under the same circumstances liquid crystals (Fig. 35) are deposited in the liver where a cirrhotic state results. Fig. 36 shows liquid crystals in bone marrow, collected into groups in the bodies of phagocytes.

Perhaps we may at some future time discover substances which will enable us to construct an artificial muscle motor exceeding the present motors in high grade of working efficiency and light in weight, by the help of which we may really copy nature's flying machines—the birds—as our aeroplanes are trying to do.

The most important result of the foregoing research is a deeper insight into the action of molecular forces, which may lead us to a more satisfactory molecular theory than the accepted one. A more profound insight into the internal mechanism of matter would be of great value to natural science on both theoretical and technical grounds, for the exact prediction of the behavior of matter is, without such insight, as little possible as the calculation of the power of a machine, the construction of which is unknown.

The Cost of Electricity at the Source*

An Important Chapter in Wooden Industrial Economics

By H. M. Hobart

The Stott-Gorsuch method is applied to the determination of the cost of manufacturing electricity in a 60-cycle station of 100,000 kilowatts installed capacity. The results correspond to the assumption that such a station is capable of delivering from 350,000,000 to 700,000,000 kelvins per annum for load factor ranging from 0.50 to 1.00. For unity load factor the cost of three-phase electricity at the outgoing cables ranges from 0.65 cent per kelvin with coal at $5.00 per ton, down to a matter of 0.20 cent per kelvin for fuel of negligible cost. A method is indicated for tracing through the increase in the cost of the electricity at later stages of its journey from the source to the consumer.

By the time electricity is delivered on the premises of small consumers such considerable costs will have been incurred that the price admitting of any profit can rarely be less than somewhere from two cents to eight cents per kelvin.[1] The original cost of manufacturing in bulk, however, is a far less amount. It is desirable that this should be more generally realized, as it indicates the great field for electricity for large manufacturing enterprises which can be located near the source of electricity supply. Under favorable conitions electricity can be manufactured in bulk at a cost of the order of 0.25 to 0.40 cent per kelvin.

In an address delivered by Ferranti[2] in 1910, the proposition was formulated that, on certain assumptions, a station equipped with ten 25,000-kilowatt generating sets could be built at a total cost of £7 ($35) per kilowatt. I have made estimates which indicate $35 per kilowatt to be sufficient for a 100,000-kilowatt station equipped with five 20,000-kilowatt, 1,800-revolution per minute, steam turbine driven, three-phase generators, and all the machinery required in such a plant. As a matter of interest it may be stated that the outlay for the turbo-generators, cables, exciters and switchgear is covered by 30 per cent of this $35 per kilowatt. (In and near large cities this sum would be insufficient, since the outlay for land and buildings would then usually be at least $10 per kilowatt.)

The following estimate for the cost of electricity when manufactured in such a station will be based on the Stott-Gorsuch method,[3] in accordance with which the total cost is considered as made up of three components. These three components are:

1. Production Costs.
2. Investment Costs.
3. Administration Costs.

I shall divide the Production Costs into two items, A and B.[4]

Item A relates to all components of the Production Costs except fuel. Item B relates to the cost of fuel. While A will vary by a small amount with the load factor, I shall neglect this variation and take:

Item A = $700,000.[5]

Item B: In estimating the annual outlay for fuel we must first have data for the overall efficiency of the station. From an examination of the thermal efficiencies of turbo-generating sets and steam-raising plant, one would be led to expect overall efficiencies from the coal to the outgoing cables ranging from at least 18 per cent for unity load factor down to at least 16 per cent for a

* Paper presented at the Second Mid-winter Convention of the American Institute of Electrical Engineers, New York, February 26th, 1914, under the auspices of the Electric Power Committee and published in the *Proceedings* of the American Institute of Electrical Engineers.

[1] In this paper the term kelvin is employed instead of the term kilowatt-hour.

[2] *Jour. Inst. Elec. Engrs.*, Vol. 46, p. 6.

[3] *Proc. Am. Inst. Elec. Engrs.*, May, 1913, p. 1099.

[4] Item A covers wages, repairs, lubricants, water, supplies, etc.

[5] It is believed that an analysis will show this value to be reasonably representative for Item A and that in so far as it errs it is in the direction of being conservative. It will cover any investment costs associated with the water supply, such as cooling towers when required.

load factor of 0.50. But reasoning from the results actually obtained in practice it is not considered that it would be conservative to take values higher than the following:

Load factor.	Overall efficiency.
1.00	15 per cent
0.75	14 " "
0.50	13 " "

Assuming the maximum load from our 100,000-kilowatt station to be 80,000 kilowatt, the annual output for these three cases is:

Load factor.	Annual output in mega-kelvins.
1.00	700.
0.75	525.
0.50	350.

The energy in the coal consumed per annum amounts to:

Load factor.	Mega-kelvins of energy in the coal
1.00	4660.
0.75	3750.
0.50	2690.

The estimates may be based on coal with a calorific value of 12,000 B.t.u. per pound.[6]

One kelvin equals 3,411 B.t.u. Consequently each (2,000-pound) ton of coal contains:

$$\frac{12,000}{3411} \times 2000 = 7000 \text{ kelvins}$$

The quantity of coal burned per annum is as follows:

Load factor.	Quantity of coal burned per annum.
1.00	667,000 tons
0.75	535,000 "
0.50	384,000 "

In the following table are set forth the outlays for fuel on the basis of 50 cents per ton and $5 per ton:

Load Factor.	Annual Outlay for Fuel.	
	50 cents per ton.	$5 per ton.
1.00	$334,000	$3,340,000
0.75	268,000	2,680,000
0.50	192,000	1,920,000

The above amount represents Item B, the fuel component of the Production Costs per annum. We have already stated that for the remaining component of the Production Costs (Item A), we shall take the constant value of $700,000.

Adding A and B we obtain the total Production Costs set forth in the following table:

Load Factor.	Production Costs per Annum.	
	Fuel at 50 cts. per ton.	Fuel at $5 per ton.
1.00	$1,034,000	$4,040,000
0.75	968,000	3,380,000
0.50	892,000	2,620,000

In terms of cents per kelvin, the above Production Costs are:

Load Factor.	Production Costs per kelvin.	
	Coal at 50 cts. per ton.	Coal at $5 per ton.
1.00	0.148 cent	0.576 cent
0.75	0.184 "	0.645 "
0.50	0.254 "	0.750 "

We now come to the second component of the total cost, namely the Investment Costs. At $35 per kilowatt the initial cost of the 100,000-kilowatt station is:

$3,500,000.

This is sufficient to cover engineering supervision and contingencies.

On the basis of:

Interest	5.0 per cent
Rates, taxes and insurance	3.0 per cent
Amortization	4.6 per cent
Total annual charges on investment[7]	12.6 per cent

we arrive at an Investment Cost per annum of

$$0.126 \times 3,500,000 = \$441,000.$$

In terms of cents per kelvin the Investment Costs are:

Load factor.	Investment costs per kelvin.
1.00	0.063 cent
0.75	0.084 "
0.50	0.126 "

As to the final item in the total cost, namely, the Administration Costs, let us distinctly limit this item to the bulk manufacturing undertaking. Let the *marketing* of the electricity be separately handled by another undertaking. With this understanding, an allowance of $100,000 per annum is reasonable for the Administration Costs. This provides for an administrative organization simply concerning itself with manufacturing the electricity and delivering it at the outgoing cables.

Per kelvin, this amounts to:

Load factor.	Administration costs per kelvin.
1.00	0.014 cent
0.75	0.019 "
0.50	0.029 "

The Total Costs are worked out in the following table in which Production Costs are indicated by I, Investment Costs by II and Administration Costs by III.

Load Factor.	Component and Total Costs in Cents per kelvin.	
	Coal at 50 cts. per ton.	Coal at $5 per ton.
1.00	I = 0.148 cent II = 0.063 " III = 0.014 " Total = 0.225 cent	I = 0.576 cent II = 0.063 " III = 0.014 " Total = 0.653 cent
0.75	I = 0.184 cent II = 0.084 " III = 0.019 " Total = 0.287 cent	I = 0.645 cent II = 0.084 " III = 0.019 " Total = 0.748 cent
0.50	I = 0.254 cent II = 0.126 " III = 0.029 " Total = 0.409 cent	I = 0.750 cent II = 0.126 " III = 0.029 " Total = 0.905 cent

These total costs are plotted in Fig. 1 with cost of coal as abscissas. They are plotted in Fig. 2 with load factors as abscissas.

For water power stations, if there is no charge for the

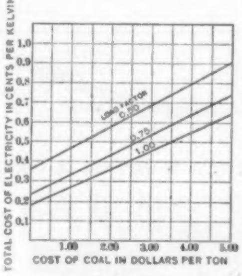


Fig. 1

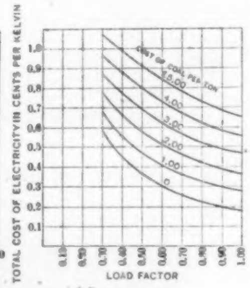


Fig. 2

water, and if the total investment can be kept as low as $35 per kilowatt, the lowest curve in Fig. 2 (i. e., the curve for fuel at a negligible cost per ton) may be taken as affording a fair indication of the cost of electricity at the source.

This investigation has been based on the assumption that the electricity delivered from the station is of unity power factor. For lower power factors the total cost of the electricity will be higher. Prof. Arno of Italy has devoted a great deal of study to the influence of the power factor on the cost of electricity and has arrived at the conclusion that for practical purposes the cost may be taken as proportional to two thirds of the true output, plus one third of the apparent output (i. e., the true output divided by the power factor). Thus if we take the case of our 100,000-kilowatt station when the load factor is 0.50, we have seen that the cost, with coal at 50 cents per ton, is 0.409 cents per kelvin for unity power factor. If the load is of 0.80 power factor the cost by the Arno rule will be:

$$\left(0.667 + \frac{0.333}{0.800}\right) \times 0.409 = 0.444 \text{ cent per kelvin}$$

Prof. Arno's rule may be regarded as a useful approximation for representative conditions. The application of the present method of analysis to outputs of different power factors would show that no such simple rule would suffice. The influence of the power factor would, for instance, be much affected by the ratio of the cost of fuel to the total costs, and would be different with different load factors.

Indeed, a similar general criticism applies to Mr. Stott's nevertheless useful approximate rule that the Production Costs may be taken as inversely proportional to the fourth root of the load factor. There may be wide deviations from such a rule occasioned by extremes in cost of fuel and in other conditions.

Furthermore, the costs which we have worked out have related to delivering 60-cycle three-phase electricity at the pressure at which it is generated, say 10,000 volts. If it is to be stepped up to, say, 100,000 volts, to be transmitted in bulk to a distance, then the cost at the high-pressure side of the step-up transformers may be obtained as follows:

Let us take the case of a load factor of 0.50 and coal at 50 cents per ton. Let the power factor be unity. The cost under these conditions has been estimated to be 0.409 cent per kelvin. We shall require to provide step-up transformers with an aggregate capacity of 100,000 kilowatts. Their cost would be of the order of $2.70 per kilowatt, making a total outlay of $270,000. The annual outlay for interest, rates, taxes, insurance, amortization repairs and attendance may be taken as:

$$0.15 \times 270,000 = \$40,500.$$

The annual output from the station when the load factor is 0.50 has already been estimated to be

350 mega-kelvins.

Taking the annual overall efficiency of the transformers as 97.5 per cent the output from the transformers is

$$350 \times 0.975 = 341.5 \text{ kelvins.}$$

Therefore, the step-up transformer costs, per kelvin delivered from them, are

$$\frac{4,050,000}{341,500,000} = 0.012 \text{ cent.}$$

The total cost per kelvin delivered from the step-up transformers is

$$\frac{350.0}{341.5} \times 0.409 + 0.012 =$$

$$0.419 + 0.012 = 0.431 \text{ cent.}$$

Thus the cost has increased 5.5 per cent by the time the pressure has been stepped-up. This paper is entitled "The Cost of Electricity at the Source." By similar processes, however, the increases in cost can be traced right through to the consumers' premises.[8] But the reasoning becomes very involved when we arrive at the stages where the electricity is no longer carried in bulk. At these stages questions relating to appraisements of value, diversity factor, ethics and commendable sentiment render it impossible to arrive at any precise method which can be conclusively demonstrated to provide for equitably distributing the total costs among the various consumers.

The Menace of the Feeble-minded

The economic and social problems connected with the feeble-minded are of far greater importance than the average "man on the street" realizes. Whatever the cause, the fact is that this class is increasing enormously in all civilized countries. Some figures in a report of the Committee of Visitors of the State Charities of New York are commented on in *The Journal of the American Medical Association*. According to this report there are in New York, at present, 32,000 feeble-minded persons. Of those, 4,900 are provided for in institutions especially designed for their care, and 4,500 in other institutions, leaving at large 22,600. It has been estimated that of the 32,000 feeble-minded, 10,000 are girls and women of child-bearing age, 1,750 of whom are cared for in institutions designed for the care of such persons, and 1,625 are confined in reformatories, prisons and almshouses, leaving about 7,000 at large in the community. Goddard estimates that, in the way of spreading disease and immorality and increasing the stock of feeble-minded, a girl or woman of this class, of child-bearing age, is three times as great a menace to the community as a feeble-minded boy or man. The Royal Commission of England reports that in that country the feeble-minded are increasing at twice the rate of the general population. The importance of providing, by the establishment of additional institutions and the completion of those under way, for the custodial care or control of a greater number of the feeble-minded cannot be overestimated. The statements of Amos W. Butler of Indiana to the effect that feeble-mindedness produces more pauperism, degeneracy and crime than any other force, that it touches every form of charitable activity, that it is felt in every part of the state and affects in some way all the people, and that its cost is beyond comprehension, are again quoted as the best argument for the policies advocated.

Lead Shot to Repair Saucepans and the Like

Small holes or leaks in sheet metal vessels can be readily stopped by using a small lead shot or a rivet, and this makes a much cleaner job than by the usual soldering which often produces an unsightly spot. First round out the hole with a knife blade or suitable tool and lay the vessel bottom up on a firm support such as flat stone or anvil so as to be able to pound firmly on the metal. Placing a small shot of suitable size in the hole, a sharp hammer stroke transforms it to a rivet. All that is needed is to file off on each side and sandpaper. It is said that even a quarter-inch hole can be thus stopped.

[6] The results of this investigation are presented in such form as to permit of ready modification to correspond to the use of fuel of other calorific values than 12,000 B.t.u. per pound.

[7] For other capital costs per kilowatt and for other rates and other depreciation assumptions the corresponding annual investment costs are readily deduced. Those adopted in this investigation would appear representative for such a station.

[8] In a paper entitled "The Relative Costs and Operating Efficiencies Polyphase and Single-Phase Generating and Transmitting Systems," Hobart (p. 115, Vol. xxxi, *Trans. Am. Inst. Elec. Engrs.*) the author has applied this method of studying in a certain case the growth of the cost of electricity commencing with the outgoing cables from the generating station and concluding with the cost as delivered from the distant sub-stations.

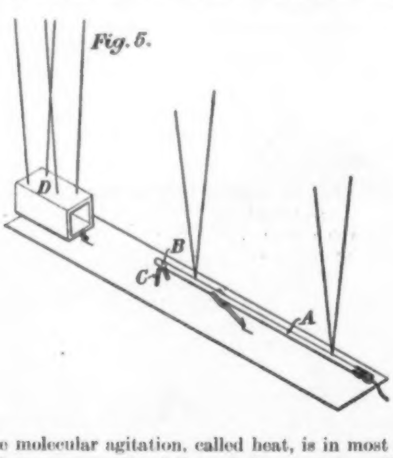
The Effects of the Detonation of Gun-cotton*

Apparatus for Measuring the Pressure Generated

By B. Hopkinson, M. Inst. C.E., F.R.S.

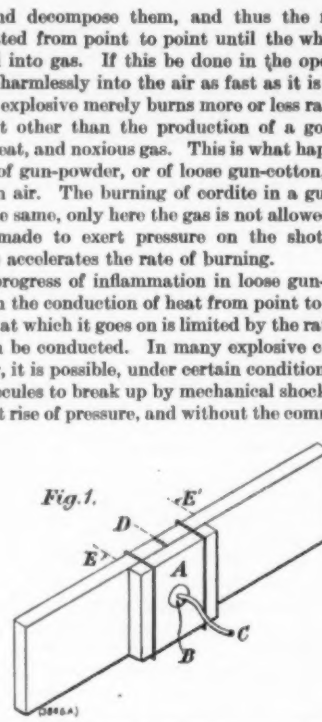
Nearly all explosives now used in practice are solid or liquid bodies whose molecules are in an unstable condition; that is, they have a tendency when disturbed to break up or decompose, changing from the condensed solid into the gaseous form. The molecule of gun-cotton may be likened to a steel envelope full of water and heated until the envelope is near bursting. A slight additional heat, or a mechanical shock sufficient to rupture the envelope, results in the rapid conversion of the water into steam. A portion of the energy which was locked up as heat in the water is thus liberated in the form of the pressure or the rapid motion of the steam, and it is this which produces the destructive effects of a boiler explosion. So the gun-cotton molecule has locked up within it, by some sort of chemical bond, a large amount of energy, and when the bond, which is not of the firmest, is by suitable means broken down, this energy appears as the pressure or motion of the gas into which the explosive is then resolved. There is, however, the difference that whereas the water is cooled when converted into steam, the gas resulting from the gun-cotton is highly heated, and this increases its pressure. The gases into which gun-cotton is converted on explosion would occupy, if allowed to expand to atmospheric pressure and cooled down, nearly 1,000 times the volume of the solid cotton. If the gases be prevented from expanding by confining the gun-cotton in an inclosure of sufficient strength, they will exert a pressure in proportion to the reduced volume which they are forced to occupy, and this pressure is still further increased by the high temperature to which they are raised. The smaller the volume of the inclosure the greater the pressure, which reaches a maximum when the gun-cotton just fits the inclosure.

The pressure developed by explosives when confined depends obviously on the volume of gas developed in relation to the volume of the inclosure, and on the temperature of that gas. We owe to Sir Andrew Noble more than to any other man our knowledge of these factors and of the resulting pressures. For determining the pressures he has used for the most part the well-known crusher-gage, which he perfected many years ago. This gage consists of a cylinder of copper which is compressed by a steel piston acted on by the pressure, just as an indicator piston compresses the spring. The amount by which the cylinder is crushed measures the pressure. Sir Andrew Noble found in this way that gun-powder confined in a bomb which it just filled gave a pressure of 43 tons per square inch. He did not find it possible to measure the pressures developed by the more powerful explosives, such as gun-cotton or cordite, when similarly confined; because no measuring apparatus was available which could withstand these pressures without damage. But by using inclosures of greater volume than the solid explosive, so that the resulting gases are less compressed, the pressure of cordite and of gun-cotton has been brought within the range of measurement. Thus it was found by Sir Andrew Noble, working with Sir F. Abel, that gun-cotton in an inclosure of about twice its own volume, gives a pressure of 50 tons per square inch. They inferred that the gases from this explosive, if they could be held within a bomb of the same volume as the solid, would give a pressure of about 120 tons per square inch.



The molecular agitation, called heat, is in most cases sufficient to upset the delicate balance of the solid explosion molecule and to convert it into the gaseous form. If the reaction be initiated by heating one part of a mass of explosive, the hot gases generated by the decomposition of this part warm up the neighboring still solid molecules and decompose them, and thus the reaction is propagated from point to point until the whole mass is changed into gas. If this be done in the open, the gas escapes harmlessly into the air as fast as it is generated, and the explosive merely burns more or less rapidly, with no effect other than the production of a good deal of flame, heat, and noxious gas. This is what happens when a train of gun-powder, or of loose gun-cotton, is fired in the open air. The burning of cordite in a gun is essentially the same, only here the gas is not allowed to escape but is made to exert pressure on the shot, and this pressure accelerates the rate of burning.

The progress of inflammation in loose gun-cotton depends on the conduction of heat from point to point, and the rate at which it goes on is limited by the rate at which heat can be conducted. In many explosive compounds, however, it is possible, under certain conditions, to cause the molecules to break up by mechanical shock, such as a sufficient rise of pressure, and without the communication of heat from outside. The way in which mechanical shock upsets the stability of the molecule is unknown; it is possible that it may be partly a temperature effect due to the heat developed in the material by the sudden application of mechanical stress, just as air is heated by rapid compression. If now a small portion of the explosive within a closely compacted mass is ignited in any manner, the gas generated is unable to escape immediately, but is confined, more or less, by the surrounding explosive, on which, for an instant, it presses with a pressure of the same order as it would exert on a steel bomb. In some explosives, for instance in cordite, the explosive would survive the pressure which would be dissipated with great rapidity as the gases escape from their confinement. In such cases the explosive may simply be scattered unburnt, or if burning continues, it will go on by the ordinary slow process of heat conduction. But if the explosive be sensitive to shock, the pressure due to the first ignited portion, fleeting though it is, may suffice to fire the adjacent layer on which it acts. This, in its turn, fires by pressure the next layer, and so the explosion is propagated from point to point, not by conduction of heat, but by the far more rapid process of transmission of mechanical pressure. The slow flow of heat in substances like gun-cotton is a matter of common experience; if a slab, 1 inch thick, be placed on a hot plate, some seconds will elapse before the heat will be sensible on the other face. But pressure applied to one side is felt almost instantaneously on the other side; it travels through with the velocity of sound, which may be several thousand feet per second.



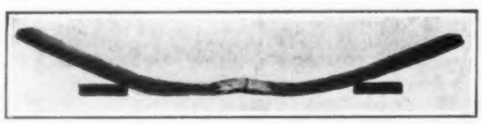


Fig. 2.—Fracture of plate of mild steel 1¼ in. thick.

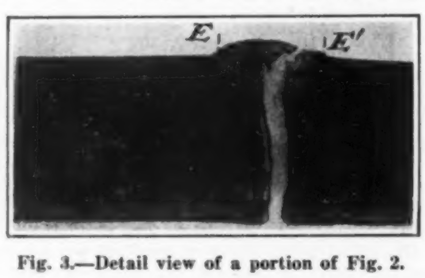


Fig. 3.—Detail view of a portion of Fig. 2.

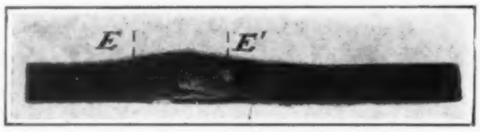
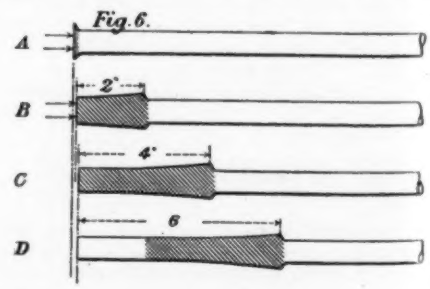


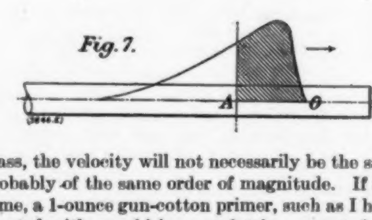
Fig. 4.—Fracture of a piece of boiler plate about 1¼ inch thick.

"Detonation" is the name given to the propagation of an explosion by a mechanical, as distinct from a purely thermal, process. It occurs only in explosive compounds, and never in mixtures such as gun-powder. Not all such compounds, however, will detonate. Evidently, for detonation to take place, the explosive must go off under the application of a pressure which does not exceed that generated when the explosive is burnt in a confined space. In cordite, which cannot be detonated, this condition apparently is not fulfilled. Where an explosive has the necessary sensitiveness to pressure for detonation to occur, it is in general also necessary that it should be closely packed, so that the pressure may be transmitted without loss from point to point. Gun-cotton, in the dry state, may be either burnt or detonated. To initiate detonation requires as a rule the production of a very high local pressure, probably of the order of 100 tons per square inch. Local heating does not usually cause gun-cotton to detonate, nor does an ordinary mechanical blow, even that of a bullet; in both cases the explosive merely burns. To produce sufficient pressure with certainty, it is necessary to use another explosive of a more sensitive kind, which detonates either when struck an ordinary blow or by the application of heat. Fulminate of mercury is the detonator generally employed in practice. A few grains are placed in a copper tube, which is inserted in a hole in the gun-cotton. The fulminate is heated by an electric current, or by the flame from a gun-powder fuse; it detonates and hits the gun-cotton in its neighborhood a violent blow, thus initiating the detonation of the gun-cotton. The fact that the copper tube must be in close contact with the cotton surrounding it shows clearly the purely mechanical origin of detonation.

When an explosive is fired in the open and the inflammation is of the ordinary kind, transmitted from point to point of conduction of heat, the gases formed can escape as fast as they are formed, and there is no appreciable rise of pressure. But since the gases and surrounding air possess inertia and must acquire velocity in order that they may get away, it is obvious that sufficiently rapid inflammation would result in a rise of pressure. Indeed, if the whole mass of solid explosive could be converted into gas absolutely instantaneously, the gas generated would, at the instant of its formation, fill the space previously occupied by the solid, and the pressure would, for that moment, be the same as if the explosive were confined in a steel bomb which it just fitted. The pressure would, of course, disappear with great rapidity by the expansion of the gas, but the maximum reached would be the same as in the bomb.

The extreme hypothetical case of instantaneous gasification is approached pretty closely—though, of course, it cannot be actually reached—when the explosive is detonated. The velocity with which detonation is propagated along a train of gun-cotton was measured many years ago by Abel. It is about 18,000 feet per second, or more than 200 miles per minute. When the wave travels radially in all directions from the center of a compact





mass, the velocity will not necessarily be the same, but is probably of the same order of magnitude. If it were the same, a 1-ounce gun-cotton primer, such as I have experimented with, would be completely converted into gas in two or three millionths of a second.

Before proceeding to describe the experimental methods which I have developed for measuring the pressure produced by the detonation of explosives, it will be well to

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, and published in *Engineering*.

say something of the practical effects which that pressure can bring about. Fig. 1 is a sketch of a plate of mild steel about 1 inch thick. Slab *A* of wet gun-cotton, of about the same thickness, is in firm contact with it on one side. A primer *B* of 1 ounce of dry gun-cotton fits in a hole, and within the primer is a fulminate detonator which can be fired by the fuse *C*. The primer is detonated by the fuse, and in its turn detonates the mass of wet gun-cotton. Thus in, perhaps, the one hundred thousandth part of a second, the whole slab is converted into gas. The effect is to smash the plate. If the gun-cotton slab is narrow, the plate will fail by a crack in the middle *D*; if it covers a greater width, there will be a crack at each edge of the slab *E*, *E'*. In the latter case a piece is blown out of the middle of the plate with a velocity of 200 feet or 300 feet per second. Sometimes this piece may be recovered whole, but more often it is broken into smaller fragments. Figs. 3 and 4 are photographs of the fracture of a plate of very good, mild steel, 1¼ inches thick. Fig. 2 is a piece of boiler-plate of about the same thickness. The gun-cotton was in each case placed on the under side of the plate in the figure, and was detonated in the open without tamping of any kind. The plate was hung up or placed on edge, as shown in Fig. 1, without other support. It is remarkable that the fractures are quite short without sensible reduction of areas, so that under the action of this particular type of stress a highly-ductile mild steel behaves like a brittle body. There is usually some distortion of the broken pieces of the plate, but there is reason to suppose that this occurs after the fracture, and that the immediate effect of the blow is to shatter, as though it were cast iron, a material which in a press can be bent double without showing a crack.

Explosives which detonate readily are of use only as destructive agents. Gun-cotton, apart from its use in the manufacture of other explosives, is chiefly interesting to military engineers, who use it for demolishing rapidly the bridges, railroads, etc., which their civil brethren have built. But the fact that it can cause mild steel to break in the curious fashion which has just been described makes its action well worthy of further study by all engineers, because of the light which such study may throw on the properties of the material with which they work. It was from this point of view that I approached the subject and tried to devise a means of analyzing the blow given by the detonation of gun-cotton.

The effect of any blow is usually defined numerically as the product of the average pressure into the time for which it acts, called the impulse. This product is quite easily measured by causing the pressure to act on a movable body of some kind, and measuring the momentum generated, which is equal to the impulse of the blow. Thus, a 1-ounce gun-cotton primer, which is a cylinder 1¼ inches by 1¼ inches, may be fixed by wooden splints to the end of a steel shaft of the same diameter (Fig. 5). The shaft is hung up by four threads so that it can swing parallel to itself, and is provided with a pencil, which marks on a sheet of paper the amplitude of the swing. When the gun-cotton is detonated, the shaft is given velocity impulsively as though it were struck a violent blow with a hammer, and the distance through which it subsequently swings is proportional to the velocity given by the blow. This is the ordinary principle of the ballistic pendulum. If the shaft be 6 feet long (weighing about 25 pounds), the velocity given to it by the gun-cotton primer will be about 4 feet per second, and if suspended by strings 50 inches long it will swing through 17 inches. The same shaft, if struck by a service rifle bullet moving 2,000 feet per second, would swing through about two thirds of the distance.

The problem is to separate the impulse so determined into two factors of pressure and time. The direct determination of the pressure factor may perhaps be described as impossible, because the pressure amounts to many

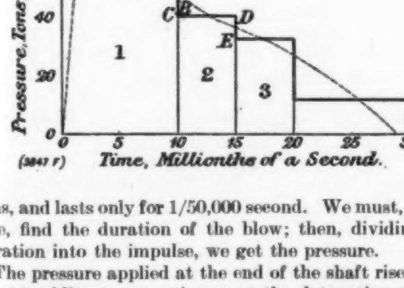


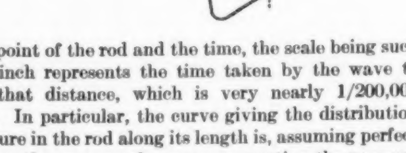
Fig. 10. PRESSURE-TIME CURVE AT SURFACE OF 1-OUNCE GUN-COTTON PRIMER

Time, Millionths of a Second.

tons, and lasts only for 1/50,000 second. We must, therefore, find the duration of the blow; then, dividing the duration into the impulse, we get the pressure.

The pressure applied at the end of the shaft rises with great rapidity to a maximum as the detonation travels through the gun-cotton, and then falls as the gases escape outward. The fall of pressure is also very rapid, but not so rapid as the rise. The pressure may be plotted as a function of the time, and the curve so obtained will be a perfectly definite thing, though the ordinates are expressed in tons and the abscissæ in millionths of a second. The result of applying this varying pressure to the end is to send along the rod a wave of pressure which travels without change of type. The progress of such a wave is illustrated diagrammatically in Fig. 6, the state of the shaft being shown at intervals of 1/100,000 second. The compression of the shaft and the lateral expansion are, of course, much exaggerated. In *D* (Fig. 6), the pressure has ceased to act, and its effects are represented by the shaded wave, now advanced some distance into the rod, the parts to right and left of which are unstrained and at rest. If the pressure in different sections of the rod be plotted at any instant (Fig. 7), then at a later time the same curve, shifted to the right by a distance proportional to the time, will represent the then distribution of pressure. The velocity with which the wave travels in steel is approximately 17,000 feet per second. As the wave travels over any section of the rod, that section successively experiences pressures represented by the successive ordinates of the curve as they pass over it. Thus the curve also represents the relation between the pressure

Fig. 8.



at any point of the rod and the time, the scale being such that 1 inch represents the time taken by the wave to travel that distance, which is very nearly 1/200,000 second. In particular, the curve giving the distribution of pressure in the rod along its length is, assuming perfect elasticity, the same as the curve connecting the pressure applied at the end and the time, the scale of time being that just given.

The progress of the wave of stress along the rod is accompanied by a corresponding strain, and, therefore, by movement. It is easy to show that the same curve which represents the distribution of pressure at any moment also represents the distribution of velocity in the rod, the scale being such that 1 ton per square inch of pressure corresponds to about 1.3 feet per second of

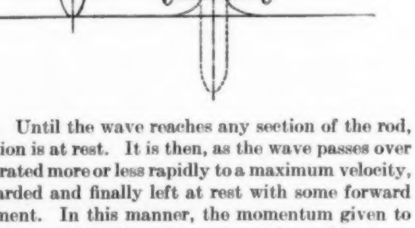


Fig. 9.

velocity. Until the wave reaches any section of the rod, that section is at rest. It is then, as the wave passes over it, accelerated more or less rapidly to a maximum velocity, then retarded and finally left at rest with some forward displacement. In this manner, the momentum given to the rod by the application of pressure at its end is transferred by the wave action along it, the whole of such momentum being at any instant concentrated in a length of the rod, which corresponds, on the scale above stated (1 inch = 1/200,000 second), to the total duration of the blow. Consider a portion of the rod to the right of any section *A* (Fig. 7) which lies within the wave at the moment under consideration. The pressure has been acting on this portion since the wave first reached it, that is for a time represented by the length *OA* and equal to $\frac{OA}{V}$ where *V* is the velocity of propagation. The momentum, which has been communicated to the part under consideration, is equal to the time-integral of the pressure which has acted across the section *A*, that is, to the shaded area of the curve in the figure. The portion of the rod to the right of the section is continually gaining momentum at the expense of the portion to the left while the wave is passing, the rate of transfer at any instant being equal to the pressure.

When the wave reaches the free end of the rod, it is reflected as a wave of tension, which comes back with the same velocity as the pressure wave, and the state of stress in the rod subsequently is to be determined by adding the effects of the direct and the reflected waves. Now, suppose that the rod is divided at some section *B* near the free end (Fig. 8), the opposed surfaces of the cut being in firm contact and carefully faced. The wave of pressure travels over the joint practically unchanged, and pressure continues to act between the faces until the reflected tension wave arrives at the joint. The pressure is then reduced by the amount of tension due to the reflected wave, and as soon as this overbalances at section *B* the pressure of the direct wave, the rod being unable to withstand tension at the joint, parts there and the end flies off. With a wave of the shape shown, having a very steep front, this happens almost immediately on the arrival of the reflected wave at the joint. The end-piece has then acquired the quantity of momentum represented by the shaded area in the figure, equal approximately to the time-integral of the pressure curve from *O* to *B*—that is, over the period of time required for the wave to travel twice the length of the end-piece. The piece flies off with this amount of momentum, so to speak, trapped within it, and the remainder is left in the shaft. The amount of momentum so trapped can readily be measured by catching the piece in a box suspended so as to form a ballistic pendulum. Dividing this by the time, *OB*, the average pressure which has acted over that interval is obtained, and this is the average pressure exerted by the gun-cotton over the corresponding interval of time. By experimenting with different lengths of piece the area of the pressure-time curve for corresponding intervals can be found, and the curve can thus be mapped. For practical purposes, however, only two lengths of piece are important. First, if the piece be short, compared with the length of the wave,* the pressure calculated as described is nearly the maximum pressure exerted; as near an approximation as is desired can be obtained by making the piece short enough. This is true, whatever the shape of the pressure-wave. Second, it is clear that if the tail of the pressure-wave has passed the section *B* when the reflected wave arrives there, the whole momentum of the blow will have passed out of the shaft into the end-piece, and the shaft is left completely at rest. This will happen if the length of the piece is equal to or greater than half the length of the pressure-wave. Thus, the duration of the blow corresponds on the scale of 1 inch equals 1/200,000 second to twice that length of piece, which just stops the shaft from moving. The general effect of the end-piece and its dependence on the sharpness of the blow may be illustrated from the behavior of a row of billiard balls touching one another and struck at one end. If the blow be a sharp one, such as is given by another ball, all remain at rest except the ball at the other end which moves off with the whole momentum of the blow; whereas the dead blow given by a cue causes all to move.

The apparatus as used for measuring gun-cotton pressures is shown in Fig. 5. The shaft *A* is hung up by four equal threads. The end-piece *B* rests in contact with the end of the shaft, its weight being taken by the support *C*, which falls out of the way when the piece is knocked off. Close contact is insured by the use of a little thick grease (e. g., vaseline) between the surfaces, or by magnetizing the shaft a little. The piece is caught in a box, *D*, suspended in a manner similar to the shaft. Both the box and shaft are provided with pencils which record on horizontal sheets of paper the amplitude of the swings. From these records the momentum trapped in the piece, and the momentum left in the shaft, can be calculated.

In order to test the method, it was applied to measuring the pressure produced by the impact of a lead bullet. This can be predicted theoretically, for lead moving with a velocity of 2,000 feet per second behaves, on impact, as though it were perfectly fluid. The bullet is fired at the end of a shaft, and then proceeds to deform, as shown in Fig. 9, the lead flowing out sideways as though it were a jet of water. The base of the bullet knows nothing of the impact of the nose, and continues to move on with unimpaired velocity as though nothing had happened. Pressure continues until the base has arrived at the shaft, and then it ceases, so that the duration of the blow is equal to the time taken by the bullet to travel its own length. The total pressure in pounds is calculated just as for a jet of water; it is $\frac{\lambda v^2}{g}$ where λ is the mass of the bullet in pounds per foot length, and v the velocity.

The service Mark VI. bullet is 1¼ inches long. At 2,000 feet per second the blow should therefore last 5.2×10^{-5} seconds, and the shaft against which the bullet is fired should just be completely stopped by an end-piece about 5.2 inches long. It was found that in

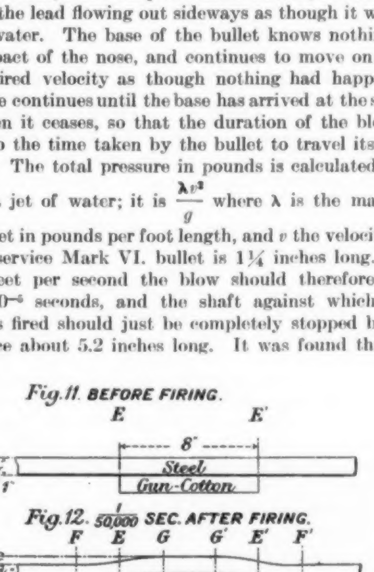


Fig. 11. BEFORE FIRING.

Fig. 12. $\frac{1}{50,000}$ SEC. AFTER FIRING.

The pressure has ceased to act. Outside FF' the metal is at rest and unstrained; inside GG' it is unstrained but has a velocity of 280 feet per second.

fact a piece 5 inches long traps 93½ per cent of the whole momentum of the blow, leaving 6½ per cent in the shaft, while with a piece 6 inches long the figures are 97½ per cent and 2½ per cent respectively. The measured duration of the blow is a little longer than it should be according to the simple theory. This is due in part to the fact that the bullet, in fact, possesses some slight rigidity, so that the base is retarded a little during the impact, instead of coming right up with unimpaired velocity. The base

arrives, therefore, a little later than it would if the bullet were quite fluid. In part, also, it is due to the fact that the pressure is concentrated on a small area in the center of the end of the rod, instead of being more or less uniformly distributed.

Good results were also obtained for the maximum pressure at different velocities, as shown in the following table:

Velocity. (Feet per Second.)	Calculated Pressure. (Pounds.)	Observed Pressure. (Pounds.)
2,000	43,500	42,600
1,240	16,700	15,700
700	5,320	5,450

The pressure per unit area in the center of the spot struck by the bullet is (at 2,000 feet per second) about 275 tons per square inch.

Having demonstrated by the experiments with bullets that this method is capable of giving within 5 per cent the duration and maximum pressure of a blow such as that of a rifle bullet, I turned my attention to gun-cotton. The shaft used in most of the experiments was of tool-steel, hardened at the end, 1½ inches in diameter by 6 feet long. The results are not yet quite ready for publication in detail, but are summarized in Fig. 10. The parallelogram marked 1 represents the momentum given to an end-piece, 1 inch long, when a 1-ounce primer is detonated in contact with the other end of the shaft. Its base represents the time during which pressure is applied to a piece of this length, viz., 1/100,000 second, and its height is the average value of the pressure exerted by the gun-cotton gases during the first 1/100,000 second—58 tons per square inch. The area of parallelogram 2 is the excess of the momentum given to a piece 1½ inches long over that given to a 1-inch piece; its height is the average pressure over the interval of 1/200,000 second following the first hundred-thousandth. The stepped line *ABCDE* is a first approximation to the pressure-time curve of the gun-cotton. Really the pressure varies continuously, more or less in the manner shown by the dotted line. This line is drawn so as to give the correct average pressures, but is, of course, conjectural as regards the details.

A piece 3 inches long on the end of the shaft stops the shaft practically dead. This is quite a striking experiment. A similar experiment can be done on a smaller scale with a fulminate of mercury detonator. The shaft in this case may be ½ inch diameter and about 2 feet long. With 10 grains of fulminate in a copper tube, the shaft is completely stopped by a 1-inch piece, showing that the blow lasts in this case for less than 1/100,000 second. The average pressure over that period is about 55 tons per square inch, the maximum at least twice as great. The study of detonators by this method may prove of practical value, because the power of a detonator probably depends mainly on the maximum pressure which it can exert on the surrounding explosive.

Further measurements with pieces of different lengths will enable the details of the pressure-time curve for gun-cotton to be filled in, and in particular will give a closer approximation to the maximum pressure, as to which it can only be asserted at present that it exceeds 60 tons per square inch. Meanwhile, the essential points, so far, may be expressed by saying that the pressure given by a 1-ounce primer lasts for about 1/50,000 second—nearly 90 per cent of the blow has been delivered in that time—and that its average value is about 55 tons per square inch. A constant pressure of that amount acting for 1/50,000 second would have the same impulse, and for practical purposes the same effect, as the actual varying pressure of the gun-cotton.

Probably figures of the same order of magnitude describe the blow given by larger slabs of the same thickness (1¼ inches), though, as the gas cannot get away quite so easily, it may be that the pressure is more prolonged.

A more concrete idea of the meaning of these figures is perhaps given by a comparison with the pressure produced by lead bullets. A cylindrical lead bullet ½ inch long and ¼ inch in diameter, striking a steel plate at 2,100 feet per second, gives a total pressure of about 15 tons for 1/50,000 second. A number of such bullets distributed with about ½ inch spacing between the centers and striking the plate simultaneously would give a blow of about the same average intensity and duration as that delivered by a slab of gun-cotton about 1 inch thick, detonated in contact with the plate and covering the area over which the bullets are distributed.

The resultant effect of applying such a blow to a sufficient area of a steel plate, 1 inch thick, is, as we have seen, to shatter the plate by developing a crack at the edge of the area to which the pressure is applied. We will now proceed to analyze this effect with the aid of the data which have been obtained as to the intensity and duration of the blow. Fig. 11 represents an edge view of the plate. The plate is supposed to be a long strip, say 8 inches wide by 1 inch thick, and the gun-cotton is a slab, 8 inches square, covering the width of the plate. The pressure of the gun-cotton gases is practically confined to the area *EE'* covered by the slab, and the immediate effect of the pressure is to set this portion in motion, leaving the rest of the plate behind. The relative motion between the portions of the plate on the two sides of the line *E* gives rise to shearing stress in the neighborhood of that line, and this is propagated by wave action both into the part *EE'*, which is subject to pressure, and into the outlying parts of the plate to the left of *E*. The wave of stress set up in this way is rather complicated, but its most important part is a wave of pure distortion, such as is caused by a long cylindrical shaft if one end is suddenly twisted. The rate at which the twist is propagated along the shaft is about 11,000 feet per second, and this is, roughly speaking, the rate at which the effects of the blow given to the middle of the steel plate travel outwards into the outlying parts.

Now consider the state of the plate 1/50,000 second later, when the pressure has just ceased to act. This is shown in Fig. 12, in which for clearness the deflections are much exaggerated. The waves of distortion which set out from *E* have got as far as *F* and *G* respectively. *EF* (and also *EG*) is the distance traveled by the wave in 1/50,000 second—viz., about 2¼ inches. Outside the section *FF'*, the metal has not felt the blow at all, and has not moved; within the section *GG'*, the metal has not felt the drag of the remainder of the plate, and has moved under the influence of the pressure, just as though it had been completely isolated by division in the planes *GG'*. The pressure which has been acting is 55 tons per square inch, and the mass of the plate is 0.28 pound per square inch. The velocity which the part *GG'* has acquired is, therefore:

$$\frac{55 \times 2{,}240}{0.28} \times 32 \times \frac{1}{50{,}000} = 280 \text{ feet per second,}$$

and the distance through which it has been shifted is:

$$\tfrac{1}{2} \times 280 \times \frac{1}{50{,}000} = 0.0028 \text{ feet, or about } 1/30 \text{ inch.}$$

The deformation represented by a deflection of 1/30 inch on a length of 1 foot or more would, of course, have no serious effect upon a plate of mild steel if it were produced by any ordinary, mechanical means. The steel, having plenty of time to flow, prefers to yield in that manner; but under the pressure of the gun-cotton gases, amounting to a total of several thousand tons, the bend is done in 1/50,000 second. At this speed, flowing is not the line of least resistance; instead of flowing, the steel prefers to crack. When a ductile solid is deformed, the stress set up depends, among other things, on the velocity of deformation, increasing with it. The stress will have, as a rule, a tensile component, tending to tear the molecules apart; but if the rate of deformation is not too great, this component will not be sufficient to overcome the cohesive forces which hold the molecules together. So long as this is the case, the material will simply flow without breach of continuity. But if the rate of deformation be increased beyond a certain point, the tensile component of stress will surpass the cohesive forces. If this should happen, even for an excessively short time and over a comparatively small area, the material is there torn apart, and the crack or tear thus initiated spreads with great rapidity. The material breaks suddenly and with little expenditure of work, like a brittle body. A stick of sealing-wax may be bent slowly through a considerable angle, and the force required to do so is small; but if it be attempted to bend it through the same angle rapidly, a much greater resistance is experienced, and it snaps. In the same way, mild steel cannot be broken short in a testing-machine or by the usual kinds of shock test, because it cannot be made to flow fast enough to cause the stress to rise to a sufficiently high value. But under the more violent shock of gun-cotton it is shattered.

Some Recent Advances in Piezochemistry*

Prof. A. W. Browne

The study of the behavior of the various forms of matter, when subjected to pressures greater than atmospheric, is of interest alike to the engineer, the physicist, and the chemist. In this field of work, the engineer is concerned not merely in the important task of measuring the strength of materials, but also in the design and construction of apparatus suitable for use in connection with the physical and chemical processes to be studied or applied. The physicist, as a rule, is interested primarily in the behavior of one component system, while the chemist investigates the reactions that take place in systems containing, in general, at least two components.

Within the past few years, a large amount of work has been done in the field of pressure chemistry, or piezochemistry, as it has been termed. It is the purpose of the present article to give a very brief account of a few of the important recent advances, some of which have already been applied on an industrial scale.

One of the most important achievements of recent years, not only in this particular field, but also in the entire domain of chemistry, has been the direct synthesis of ammonia from its elements.[1] This has been accomplished by Prof. Haber and his associates, and the process has been developed on a commercial scale by the Badische Anilin & Soda Fabrik. It had long been known that minute quantities of ammonia can be formed by the action of the electric spark, or the silent discharge, upon a mixture of nitrogen and hydrogen. Many experiments had been performed under various conditions by earlier investigators in the hope of increasing the amount of ammonia formed, but without appreciable results, although a pressure as high as 75 atmospheres had been used by one investigator, and the action of several different catalytic agents had been studied. By working under a pressure of 200 atmospheres, however, at a temperature of from 650 deg. to 700 deg. Cent., and using a catalytic agent prepared from the purest iron oxide, Haber found it possible to obtain ammonia at the rate of 250 grammes per hour per liter of contact space. With certain other catalytic agents somewhat lower temperatures can be employed. The ammonia formed may either be drawn directly from the apparatus in the anhydrous liquid condition, or it may be absorbed with the aid of water.

The great importance of the Haber process lies in the fact that it opens one more way to the chemical fixation of nitrogen, and thus to an increase in the world's supply of available nitrogen. Another fruitful result of the investigation has been the increase in our knowledge of the technique necessary in work in which high pressures and high temperatures are used at the same time. The successful culmination of this research will, no doubt, serve as an incentive to much further investigation along various lines in the field of piezochemistry.

During the past year, F. Fisher and O. Priess[2] have succeeded in preparing hydrogen peroxide on a laboratory scale by reduction of oxygen gas, dissolved under pressure. The reduction was effected by nascent hydrogen, evolved either electrochemically, in which case very dilute sulphuric, phosphoric, or boric acid served as the electrolyte, or chemically, from zinc amalgam and dilute sulphuric acid. In the first part of the work the effect upon the yield of hydrogen peroxide, of using oxygen instead of air, of varying the pressure, temperature, current density, amount of stirring, and of using various electrolytes and electrodes was carefully studied. It was found, for example, that under a pressure of 100 atmospheres a 2.7 per cent solution of hydrogen peroxide could be obtained in 200 minutes with a current density of 2.3 ampères per square dekameter. This corresponds to a current efficiency of 83 per cent, and to a production of 350 grammes of peroxide per kilowatt hour. In the second part of the work, a number of metals were tried with sulphuric acid and with fluosilicic acid under normal and under increased pressure of oxygen. It was found, for example, that under a pressure of 25 atmospheres, 2 grammes of hydrogen peroxide per liter was obtained after 10 minutes from 25 square centimeters of liquid zinc amalgam in 60 cubic centimeters of one per cent sulphuric acid.

A rather extensive series of investigations has been carried out by E. Cohen and his colleagues,[3] which, although at present of scientific interest only, should be of material assistance in paving the way toward ultimate practical applications of high pressure in chemical work. In connection with their researches, these investigators have constructed an apparatus capable of automatically maintaining pressures up to 1,500 atmospheres constant to within one per cent. The effect of pressure upon the velocity of inversion of cane sugar at 25 deg. Cent. by dilute hydrochloric acid was investigated over the interval from 1 to 1,500 atmospheres. At pressures of 500, 1,000 and 1,500 atmospheres, respectively, a diminution in velocity of 8, 19 and 26 per cent was observed. From these results it is apparent that the influence of pressure upon liquids is by no means negligible. In another research, the validity of Faraday's first law (one way of stating which is that the amount of chemical action is proportional to the quantity of electricity that passes through the cell), at pressures up to 1,500 atmospheres was established with an accuracy of 1 in 17,000 by weighing the amounts of silver deposited during the electrolysis of silver nitrate solutions.

The chemical decomposition of nitric oxid, NO, at pressures of from 50 to 700 atmospheres, and over a wide range of temperatures, has been studied by Briner and

* Reproduced from the *Sibley Journal of Engineering*.

[1] For a rather detailed popular account of this work, reference should be made to the lecture delivered by Dr. Bernsthen before the Eighth International Congress of Applied Chemistry (New York, 1912), and published in the *Report* of the congress, vol. 28, pp. 182–201.

[2] *Berichte der Deutschen chemischen Gesellschaft*, 46, 698–700 (1913).

[3] For the last three articles of the series, see *Zeitschrift für physikalische Chemie*, 84, 32–40, 41–82, 83–90 (1913).

Boubnoff.[4] From the results of about 50 experiments, it was concluded that two principal reactions take place, with formation in the first instance of nitrogen and oxygen gases, and in the second of nitrous oxide and oxygen. The higher oxides, N_2O_3 and NO_2, are considered to be formed as the result of secondary reactions. It was found by Briner[5] that with an initial pressure of 50 atmospheres only a very small amount of nitrogen trioxide was formed at ordinary temperature, even after a period of one year. With a pressure of 700 atmospheres, however, one half of the maximum amount theoretically obtainable was produced in 40 minutes. This illustrates very clearly the acceleration of chemical action that may sometimes be effected by increase of pressure.

Some very interesting and important results have been obtained by F. Bergius[6] in connection with an investigation of certain high pressure reactions. By heating wood or some other material consisting chiefly of cellulose to 340 deg. Cent. in the presence of liquid water, Bergius found the cellulose to undergo decomposition, with loss of carbon dioxide and water, and with evolution of heat. After 19.5 hours, in one particular experiment, the percentage of carbon in the residual, coal-like mass became constant at about 84.7. When this product, which in some respects resembled bituminous coal, was subjected to a hydraulic pressure of 5,000 atmospheres at 340 deg. Cent. for a period of 46 hours, a gas mixture consisting chiefly of methane, but containing a small amount of carbon dioxide, was evolved, while the percentage of carbon in the residue rose to 88.2. This residue is said to have resembled anthracite coal. The formation of bituminous and anthracite coal in nature is believed by Bergius to have taken place in a way somewhat similar to that illustrated in his experiments, although of course very much more slowly because of the lower temperatures prevailing on and near the surface of the earth. His experiments were not performed, however, with the sole object of investigating the geochemical problem of coal formation. Another important object has been the attempt to determine the chemical constitution of coal. Definite information upon this point would undoubtedly be of value as a guide to the most efficient practical utilization of coal.

Bergius has also performed a number of other experiments at high pressures. By heating lime, for example, dissolved in a molten mixture of sodium hydroxide and potassium hydroxide, to 350 deg. Cent. in a bomb containing oxygen gas under a pressure of 120 atmospheres, he obtained calcium dioxide, CaO_2. From iron and liquid water heated to 340 deg. Cent. under great pressure he has prepared large quantities (1,000 cubic meters per day) of very pure (99.95 per cent) hydrogen gas.

V. Ipat'ev and his associates, who have published a long series of articles on the subject of catalytic reactions at high temperatures and pressures,[7] have recently shown that hydrogen gas at high pressures and temperatures will displace various metals from aqueous solutions of their salts.[8] The familiar reaction between metal and acid, with formation of salt and hydrogen, is thus shown to be reversible under proper conditions.

A preliminary study of the behavior of numerous substances, chiefly inorganic salts, in sealed glass tubes toward anhydrous ammonia and toward anhydrous sulphur dioxide at temperatures ranging from −80 deg. to +160 deg. Cent., and under pressures sometimes as high as 130 atmospheres, has recently been completed in the Cornell laboratories by Fritz Friedrichs.[9] On the basis of his observations he has formulated a new classification for binary systems which, it is hoped, may in addition to other uses be of some assistance in connection with the development of the theory of the so-called hydrothermal processes which are now under investigation in the hands of the research geologist and the geophysicist.

A most ingenious and useful application of pressure to a chemical reaction is that made by L. H. Baekeland in connection with the manufacture of the commercial product known as bakelite.[10] When equal amounts of phenol and formaldehyde are treated with a small amount of an alkaline condensing agent and heated, the resulting mixture separates into two layers, a supernatant aqueous solution, and a heavier substance known as the initial condensation product, A. This first product may be transformed into B, the intermediate, or into C, the final condensation product, which is an insoluble, infusible substance, resistant to the action of nearly all chemicals, and which is an excellent insulator toward heat and electricity. When A is heated at atmospheric pressure to temperatures above 100 deg. Cent., vapors are given off, and a porous mass of C is obtained. If, however, the heating be accomplished under an air pressure of about 100 pounds per square inch, the final product becomes compact and coherent. The function of the pressure in the "bakelizer" is therefore simply to prevent porosity by overcoming the vapor tension of the initial product. Liquid A may be used to impregnate substances like wood, to coat various surfaces, and may be used as a binder for any inert filling material. In every case, the object or substance must of course be heated to insure conversion of A into the final condensation product C. The various applications of this product that have been suggested are so numerous that only a very few will be mentioned here. It is used as a substitute for amber in pipe stems and similar articles. It may be fashioned into knobs, buttons, knife handles, billiard balls, valve seats, insulating materials of various sorts, phonograph records, and many other articles of very diverse nature.

The advances briefly noted in the foregoing paragraphs represent but a small percentage of the total amount of work that has been carried out within the past few years in the field of piezochemistry. And yet the chemist is still only at the threshold. For the next ten years at least, growth in this field should be increasingly rapid.

[4] *Comptes rend.*, 156, 228–30 (1913).

[5] *Zeitschrift für Elektrochemie*, 19, 301 (1913).

[6] *Zeitschrift für Elektrochemie*, 18, 660–2 (1912); 19, 609–10, 858–60 (1913). *Engineering*, 96, 262–3, 564 (1913). *Jour. of Gas Lighting*, 119, 571.

[7] See, for example, *Chemical Abstracts*, 6, 736, 1,280 (1912).

[8] *Berichte der deutschen chemischen Gesellschaft*, 42, 2,078–88 (1909); 44, 1,755–8 (1911); 45, 3,226–9 (1912). *Chemical Abstracts*, 6, 1,104 (1912).

[9] *Journal of the American Chemical Society*, 35, 1,866–83 (1913).

[10] *Journal of Industrial and Engineering Chemistry*, 1, 149, 545 (1909); 3, 932 (1911); 4, 737 (1912); 5, 506 (1913).

Causes of Accidents With Airships*

Faults of Construction and Maneuvering and Other Determining Factors

By Ing. Enrico Forlanini

In investigating the causes of accidents to airships, losses due to mistakes in design and faults of construction may first be reviewed. These include the accidents to the Bradsky airship, 1902, the "Republic," 1908, and Erbslöh, 1910. In the Bradsky, the gondolas, suspended by steel wires from the gas-bag, fell when the ship was at a height of 100 meters, and the crew were killed. Owing to defects of propeller design, a blade of the "Republic's" screw flew off, struck and burst the envelope, bringing the airship to the ground, and killing the crew. In the case of the Erbslöh, the gas-bag burst, due to the expansion of the gas when the airship "came from the shadow of clouds into the sun during a rapid rise." With this design, there is no doubt the safety-valves on the envelope were much too small.

Defective maneuvering on the ground, and insufficient means for carrying out such maneuvering, have been the cause of many losses. Imprudence and too great daring on the part of the aeronauts have been the cause of several disasters, owing in a measure to an excessively zealous interpretation of the requirements of military discipline. The "Zeppelin L 1" was shipwrecked on September 9th, 1913, at Heligoland. Capt. Hane, in command, risked dangers in exhausting nearly all his ballast.

The two principal causes of accident with airships are: first, fire; and, secondly, gusty and violent winds accompanied by snow, rain, or hail. A whirling and severe wind is exceedingly dangerous, and cannot be altogether avoided. So long as there are airships, there will be wrecks, and the analogy of the ship on the sea may be drawn; with the latter, the cumulative experience of many years has not succeeded in eliminating, although it has greatly diminished, the risks of shipwreck. Airships, however, ought not to catch fire if the lessons of experience have been well assimilated, and the conditions should be made to approximate to those on board ordinary ships with exactly the same chance of fire. Yet 5 per cent of all airships constructed have perished by fire—half of the total have been burned in the air, with the loss of all on board. In 1897 the "Deutschland," commanded by Woelfert, was lost in this way. This airship had a bamboo gondola, in which was an 8 horse-power Daimler gasoline engine close to the gas-bag. This was the first application of the gasoline engine to airships. Before starting, flames were noticed to come from the engine, but Woelfert was quite confident, and the airship rose rapidly. When in the air, the steering-gear broke and the airship revolved at a height of 100 meters; an explosion took place, and the airship crashed to earth in flames. In 1902, the Brazilian ship "Pax," provided with two gasoline engines, giving a total of 400 horse-power, in gondolas very near to the gas-bag, made a rapid rise to a height of 400 or 500 meters, when a flame was seen, followed by a violent explosion, and the crew of two were killed. Owing to the rapid rise and the sun's rays, the gas issued from the safety-valves, with which this airship was provided, in the bottom of the gas-bag.

Three Zeppelins have been burned, but the "Zeppelin L 2"—the most recent ship destroyed—is the only one which was burned in the air. In connection with the Zeppelins and their disastrous history, it is only fair to state that less than 20 Zeppelins have carried out 2,000 flights, many of great distances, carrying a total number of 40,000 persons; they thus surpass, in performance, all other airships. On October 17th, 1913, the Zeppelin airship "L 2" rose rapidly to a height of 200 meters, when flames were seen to issue from the forward part of the forward gondola; the forward part of the airship caught fire, and shortly afterward the after part of the wrapping, disclosing to view the gas-bags inside the structure. Two seconds afterward, a terrible explosion took place, shaking the aeroplanes flying in the neighborhood. During the airship's fall several explosions were heard, and the crew of 28 were killed. The official explanation of this disaster cites three causes pre-eminently contributory: 1. The wind-screen fitted on the forward end of the bow-cabin was an innovation, and differed from previous practice with Zeppelins, and is stated to have caused a back suction in the gondola. This suction would have drawn escaping gas from the safety-valves fitted on the lower part of the gas-bag into the engine space. 2. The corridor of communication between the gondolas, previously fitted externally to the main structure, was placed in the framework of the airship. 3. The gondolas were fitted nearer to the body of the ship. It is interesting to record that the three modifications just cited caused considerable dissensions between Count Zeppelin and his advisers and the naval authorities in Germany. Zeppelin doubted the safety of this new type, "L 2," and did not consider it as good as previous types, and although conscious of the advantage of compactness and efficiency given by the design, yet he had an instinctive distrust of it.

The long list of airships which have been burned is indicative of the lines upon which future progress must take place. An analysis of these accidents reveals the same defects in all the designs: 1. The gondolas near or adhering to the gas-bag. 2. The escape-valves placed in the lower part of the envelope. With valves placed on the side or on the top of the gas-bag, no cases of burning, so far as is known, have been recorded. The theory of the variation of volume of gas, due to height and temperature, may be explained as follows: When the gas is warmed, due to the sun's rays or other causes, and is increased in volume accordingly, gas escapes by the safety-valve. When the airship increases in altitude the gas expands, due to the decreased atmospheric pressure, and so also escapes by the safety-valve, and escapes more rapidly the quicker the ascent of the airship, especially in sunny weather. The speed of escape is primarily governed by the velocity of ascent. Conversely, when the airship descends, the gas contracts, due to compression, and the envelope becomes flabby, and pockets and folds are formed in the surface. The latter increase the external resistance, so that means must be taken of keeping the surface symmetrical; this is attained in two ways:

1. Ballonets or air-pockets are generally employed for compensation, and are permitted to become flabby. The air is kept at a slight pressure by means of a fan or in some other suitable way, and the pressure is transmitted through the flabby walls of the ballonet to the gas in the balloon, and keeps the whole main envelope stretched from end to end and of a constant form. If the volume of gas be diminished, the volume of the ballonet is augmented by the fan, and so makes up for the diminution of volume from gas. If, on the other hand, the volume of the gas increases, the ballonet air escapes through the same piping as served for the supply of air from the fan or through suitable air-valves. The Parseval type of airship is constructed on this principle, with compensating chambers of two ballonets inside the gas balloon, but more frequently the same principle essentially is applied, though slightly altered in form, by having, inside the main gas-bag, instead of ballonets, a flabby diaphragm as near as possible horizontal in position, dividing the capacity of the envelope into two unequal parts, the upper or larger one for gas, and the lower one for air. The lower serves the purpose of the air-pocket.

*Translation from the Italian magazine *La Lettura*, published in *Engineering*.

2. The second system of compensation is that used in Zeppelin ships, where a metallic framework is covered by stretched fabric. Within this envelope a certain number of ballonets for gas are fitted. These may freely contract or dilate without altering the external form of the envelope. With this design, pockets of air are replaced by the space between the ballonets and the exterior envelope, which space, of course, enlarges or contracts in volume as the ballonets contract or enlarge. As already stated, the gas expands due to the causes mentioned, and when all the space in the main gas-bags has been filled, the gas escapes by valves fitted for this purpose. In addition, besides escaping owing to excess of pressure, the gas may escape from these valves at the will of the aeronaut who controls these valves, opening them to prevent the airship from going too high or for bringing it to the ground. The position of the escape-valves is fixed by the constructor.

It would seem obvious that valves through which such highly inflammable gas will pass should be fitted far away from the main engines. Almost always they are placed at the highest part of the envelope. Since the gas rises rapidly by virtue of its exceeding lightness and its velocity, it cannot then come into contact with the main motors. This need of fitting the valves in the highest part of the envelope is not always remembered, and some airships, in fact, have had valves in the lowest part—e. g., the "Deutschland," the "Pax" and, even at the presen time, the "Zeppelin."

In these airships, the valves, instead of allowing the gas to escape to the atmosphere, permit it to pass to the space for the compensating air—i. e., between the diaphragm and the lower part of the envelope in the "Deutschland" and the "Pax," and in the "Zeppelin" into the space between the main gas-bags and the exterior envelope.

It is well known that hydrogen and air mixed in suitable proportion forms an exceedingly explosive mixture, and this is the cause of the explosions mentioned. The simple burning of the hydrogen, not a mixture of hydrogen and air, means, of course, a total loss of the airship, but gives a possibility of escape to the crew, since the combustion is gradual and not of the instantaneous nature of an explosion. More especially is this so with airships subdivided into various compartments. Burning would probably take place very rapidly, and the airship would descend almost precipitately, but not necessarily in such a way as to be fatal to those on board.

The circumstances which give rise to the greatest danger of fire are: 1. Where the gondolas are near the envelope they aggravate the danger, but are not in themselves a grave danger. 2. Danger arises when the closeness of the gondola is associated with a wrong position of the escape-valves—i. e., in the bottom of the envelope—and still more is it dangerous when the escaping gas does not go immediately to the atmosphere, but mixes with air in a compensating air-chamber, when it may form an explosive mixture. 3. Rapid expansion of the gas, due to a rapid ascent of the airship. As already mentioned, 5 per cent of all airships constructed have perished by fire, and an analysis of accidents shows that 25 per cent of those which have the gondolas adhering to the gas-bag, and the escape-valves in the lower part of the envelope, have burned. This type is exceedingly dangerous, even when the large number of long flights and the great number of passengers carried by the "Zeppelin" are remembered. The Zeppelins, of course, belong to this category.

In the press it is often stated that the dangers of fire are mainly due to the adoption of the rigid form of construction; but this argument is far from conclusive, although it is true that rigid construction permits of a gondola close to or attached to the envelope—in fact, the gondola may even be placed right inside. It s to be understood that the rigid construction permits of this closeness of the gondola, but in no way necessitates it, and there is no difficulty in adopting with the rigid type a gondola at a distance from the gas-bags, as is frequently done, and is necessarily the case with non-rigid airships. An advantage, of course, of placing the gondola as close to the gas-bag as possible is that the air resistance is decreased, the horse-power required for a given speed reduced, and the radius of action augmented.

Other dangers of fire are: 1. The main engines, gasoline, electric conductors, leads and magnetos of the engines. 2. The highly inflammable nature of the gondola material. 3. The lubricating oil in the various parts of the mechanism. Proximity of the engines to the gasoline tanks is exceedingly dangerous, due to the extreme volatility and nature of the fuel, even at low temperatures. The advent of the heavy-oil, or even the paraffin, engine for airship propulsion is eagerly awaited as the greatest contribution to progress in the solution of the difficulties encountered in avoiding dangers of fire. It can confidently be stated that the dangers of fire would be decreased by the use of such motive power by at least 90 per cent.

The effects of lightning are almost negligible; the experience of ordinary balloons during thunderstorms proves this. Only one case is known—that in Rome, in 1908, where a balloon struck by lightning was "fired." An airship is less exposed to such danger than a balloon, because it can remain at will at a distance from the storm. To avoid such a danger completely, descent is necessary, unless the conditions of the ground or high wind are more dangerous than those of lightning.

In conclusion, a few particulars are given of the airship "Città di Milano,"[1] designed by the author, explaining how the dangers of fire have been guarded against:

(a) Escape-valves for the gas are provided in the highest part of the envelope. The general structure bears a slight resemblance to that of the "Zeppelin," in that the gas envelope is surrounded entirely by a second envelope, forming thus an annulus of air round the gas envelope. The resemblance ceases here. At the escape-valves, the two envelopes are joined together, thus allowing the gas to escape, not into the annular space, but into the open atmosphere. This precludes the gas escaping at the top of the envelope from reaching the main engines. Since the gas escapes into the open air instead of into the air space inside the envelope, the formation of an explosive mixture is prevented; in extreme cases it is possible, but not in any way probable, that an explosive mixture might be formed by some damage to the gas envelope, causing the gas to mix with the air in the annulus. In such cases, this mixture would be immediately expelled from the annulus through vents in the highest part of the envelope by a ventilating fan which is always kept running.

(b) The two engines, each of 80 horse-power, are inclosed in a rectangular casing, the walls of which are made partly removable. The fixed walls are of aluminium, and the portable doors of wire-woven asbestos cloth. The interior of this casing is well ventilated by the fan that serves to draw air through the cooling-water radiator, and in this way the accumulation of explosive vapors of gasoline and air inside the casing is precluded.

(c) The exhaust-pipes of these engines generally run red hot, but in this case they are inclosed in a sleeve of aluminium, suitably ventilated to cause the passage of a current of cold air at a speed of 20 meters per second. In this way, the exhaust-pipes are kept cool, and the aluminium sleeve is at such a temperature that the hand can always be applied thereto.

(d) In this way there are two currents of air, that in the casing and that for the exhaust-pipe, both of which are deflected into the exhaust-pipe to mix with the products of combustion of the main engine, and considerably lower their temperature before they leave the engine casing. The engine exhaust is arranged to pass away under the flooring of the gondola; and to prevent danger from any incandescent sparks of soot which might remain in the products of combustion, the lower walls of the gondola are sheathed externally with aluminium for an area of 10 square meters around the mouth of the engine exhaust-pipe.

(e) The engines have two carbureters, which are a source of danger, due to the liquid gasoline contained therein, and to the possibility of a back-fire from the cylinders. These carbureters are inclosed within metallic boxes, to which the air for combustion is led in long pipes from the atmosphere at a point remote from the engines. In this way, the momentum of the incoming air smothers any back-fire.

(f) Within the motor casings, at a height of 1 meter, is provided a roof of 10 square meters of corrugated aluminium sheet, covered by sheet asbestos on its upper side. The efficiency of this roofing was tested by a gasoline lamp, which was allowed to play on the aluminium sheet until it melted, and it was noted that this was insufficient to burn material placed above the asbestos sheet, such material only becoming blackened and partly carbonized.

(g) The materials which cover the gondolas are made non-inflammable by immersion in salts of ammonia, and only carbonize, without flame.

(h) The gasoline-tanks are placed at a distance of some 10 meters from the main engines, and are connected together on the vertical line passing through the center of gravity of the airship, and are in an atmosphere which is continuously ventilated by the air which escapes from the air-chamber, and is separated from the engine-room by means of a diaphragm of non-inflammable and water-proof material.

(l) The pipe for the gasoline from the reservoirs to the engines is strong, and is not rigidly supported. The various shut-offs are made by means of valves, with an absolute dead shut-off, with tallow-packed glands.

(m) The pressure which it is necessary to maintain in the gasoline reservoirs is obtained from a bottle of carbon dioxide, instead of the more usual compressed air, so as to obviate the formation of any explosive mixture in any of the gasoline-tanks.

(n) Two fire-extinguishers are always carried in the gondola, as well as sheets of asbestos, in order to put out any flame which from any unforeseen cause might be generated.

No absolute guarantee, of course, can be given of immunity from fire, as all the ingenuity and provision made by those working with the most sincere and best intentions may at any time be completely nullified by fate; but the intenseness and earnestness of these intentions are always tending toward the remoteness of the dangers arising from fire. Although in the "Città di Milano" much has been done in this direction, still more radical systems are being applied to airships now under construction.

[1] Of this type of airship four have been ordered for the British Navy.

Correction

In W. P. Davey's article on page 198 of our issue of March 28, the following errata require correction. The equation

$$I_2 = I_1 \epsilon \lambda x$$

should read

$$I_2 = I_1 \epsilon^{-\lambda x}$$

In reference (30) the symbols ää6 should read 136. Reference 6 should read J. de Beaujeu, Arch. d'Electr. Med. May 25, 1910.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, APRIL 18, 1914

Published weekly by Munn & Company, Incorporated
Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer
all at 361 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

The Scientific American Publications

Scientific American Supplement (established 1876)	per year	$5.00
Scientific American (established 1845)	"	3.00
American Homes and Gardens	"	3.00

The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application

Remit by postal or express money order, bank draft or check

Munn & Co., Inc., 361 Broadway, New York

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